From: Nomellini, Grilli & McDaniel PLCs [mailto:ngmplcs@pacbell.net]
Sent: Tuesday, November 23, 2010 10:25 AM
To: Grindstaff, Joe@DeltaCouncil
Cc: Zuckerman, Tom@talavera.us
Subject: FW: Fish Screening Info

Joe: Tom asked that I forward this to you. He was leaving town and reported that he could not open the attachment. If you have a problem let me know and I will resend in a different manner. Dante Sr

---

From: Nomellini, Grilli & McDaniel PLCs [mailto:ngmplcs@pacbell.net]
Sent: Friday, November 19, 2010 4:24 PM
To: 'Tom Zuckerman (tmz@talavera.us)'
Subject: Fish Screening Info

Attached please find the fish screening info as you requested.

Nomellini, Grilli & McDaniel
Professional Law Corporations
235 East Weber Avenue
Stockton, CA 95202
Mailing Address:
P.O. Box 1461
Stockton, CA 95201-1461
Telephone: (209) 465-5883
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DIRECTORS
George Biagi, Jr.
Rudy Mussi
Edward Zuckerman

COUNSEL
Dante John Nomellini
Dante John Nomellini, Jr.
Thomas M. Zuckerman

CENTRAL DELTA WATER AGENCY
235 East Weber Avenue • P.O. Box 1461 • Stockton, CA 95201
Phone 209/465-5883 • Fax 209/465-3956

November 18, 2004

Debbie Irvin, Clerk of the Board
State Water Resources Control Board
P. O. Box 100
Sacramento, CA 95812

Re: Workshop - Periodic Review
Water Quality Control Plan for the San Francisco Bay/
Sacramento-San Joaquin Delta Estuary

Dear Members of the SWRCB:

Submitted hereby are an original and sixteen (16) copies of the following:

Attachment A includes copies of the Exhibits related to screening In-Delta diversions to which I made reference at the October 28, 2004, workshop. Exhibits WRINT CDWA 1 through 10 were submitted to the SWRCB in August of 1992.

Attachment B is a copy of a December 28, 1992, letter from DWR transmitting the results of the testing performed by CDFG and DWR on the McDonald Island Delta-Siphon Fish Screen Test Project.

Attachment C is our December 17, 1993, letter to Gary Matlock, Acting Regional Director NMFS.

Our views remain the same as expressed in our December 17, 1993, letter.

Respectfully submitted,

DANTE JOHN NOMELLINI
Manager and Co-Counsel

DJN:ju

ATTACHMENT A

ENCLOSURE 4

PROCEEDINGS FOR THE SAN FRANCISCO BAY/SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

INDEX OF EXHIBITS

PARTICIPANT CENTRAL DELTA WATER AGENCY PAGE 1 OF 2

PHASE	DATE	EXHIBIT NUMBER	NAME OF AUTHOR OR PREPARER OF EXHIBIT AND DESCRIPTIVE TITLE OR CLEAR EXPLANATION OF THE CONTENTS OF EACH EXHIBIT (USE MORE THAN ONE LINE PER EXHIBIT AS NEEDED)	WITNESS TO BE USING THIS EXHIBIT	REFERENCED (YES/NO)	COST	NO. OF COPIES WANTED*
Interim Rebuttal	August 3-4, 1992	WRINT CDWA 1	Screening Agricultural Diversions in the Sacramento-San Joaquin Delta: Randall L. Brown	Nomellini	No	$.30/pg	
		2	Loss of Striped Bass Eggs and Young through small Agricultural Diversions in the Sacramento-San	Nomellini	No	$.30/pg	
			Joaquin Delta: David H. Allen				
		3	Irrigation Diversion Study Summary: vs. Fish and Wildlife Service	Nomellini	No	$.30/pg	
		4	Screening Existing Agricultural Diversions in the Sacramento-San Joaquin Estuary and its Tributaries,	Nomellini	No	$.30/pg	
			a Review of the Problem: Dan B. Odenweller				
		5	Area Map - Location of McDonald Island Siphon Screening Test Site	Nomellini	No	$.30/pg	
		6	Lakos IPC Series Self-Cleaning Pump Intake Screens Diagram	Nomellini	No	$.30/pg	
		7	Application Sketch: Lakos Plum Creek Fish Screen	Nomellini	No	$.30/pg	
		8	Resume of Dante John Nomellini	Nomellini	No	$.30/pg	
		9	Rebuttal Testimony of Dante John Nomellini	Nomellini	No	$.30/pg	

(If more space is required, please add additional pages)

*** RESERVED FOR PARTIES REQUESTING COPIES OF EXHIBITS.**

SEND REQUESTS FOR COPIES OF EXHIBITS AND REMITTANCE TO:

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Stockton, California 95201-1461

FOR0092R1

PROCEEDINGS FOR THE SAN FRANCISCO BAY/SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

INDEX OF EXHIBITS

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Interim Rebuttal	August 3-4, 1992	10	A Survey of Anadromous Fish Losses in Irrigated Diversions from the Sacramento and San Joaquin	Nomellini	Yes		
			Rivers: Richard J. Hallock and William F. Van Woert: "California Fish and Game", Vol. 45,				
			No. 4, October, 1959				

(If more space is required, please add additional pages)

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END OF DOCUMENT

SCREENING AGRICULTURAL DIVERSIONS IN THE SACRAMENTO-SAN JOAQUIN DELTA

BY

RANDALL L. BROWN

INTRODUCTION

The Sacramento-San Joaquin Delta (Figure 1) consists of numerous islands and channels located at the confluence of California's Sacramento and San Joaquin Rivers. The islands are surrounded by levees and are intensively farmed. Channels serve as homes for many resident species of fish and as pathways for migratory species such as chinook salmon and American shad. A resource conflict develops when farmers divert irrigation water from channels by means of pumps and siphons. Because the agricultural diversions are not screened, they entrain various fish life stages, particularly eggs, larvae, and juveniles. The most commonly used irrigation methods in the Delta, subsurface and overhead sprinklers probably result in complete mortality of those organisms entrained in the diversions.

The Department of Water Resources (DWR) examined agricultural diversions in some detail to estimate fish losses caused by entrainment, primarily losses of juvenile chinook salmon and striped bass, and the technical feasibility of screening the hundreds of diversions located in the Delta. This report documents the results of this study. It must be pointed out that there are very few data available on diversion rates, losses through diversions, effective screen designs for the Delta pumps and siphons, or the potential costs associated with installing and maintaining effective screening systems. I was forced to make a lot of assumptions and to stretch the available data past comfortable limits. Because of the above limitations, the report contains only suggestions as to the magnitude of fish losses and the costs of screening. No attempt has been made to extrapolate from losses of small fish to the impact of the projected losses on adult populations.

For purposes of this report, the discussion of fishery resources is generally limited to populations of chinook salmon and striped bass that pass through and/or live in the Delta. The reasons for this limitation are two-fold. First, these two animals are economically the most important fish in the system; second, more data exist for these fish than any others. Other fish species are briefly discussed when data are available.

BACKGROUND INFORMATION

The environmental setting for the Delta and its primary fish and wildlife resources has been thoroughly described in numerous publications (see, in particular, DWR, 1974; PGandE, 1981; and DFG, 1966) and need not be described in detail here. There are, however, a few comments which may provide the

WRINT CDWA EX 1

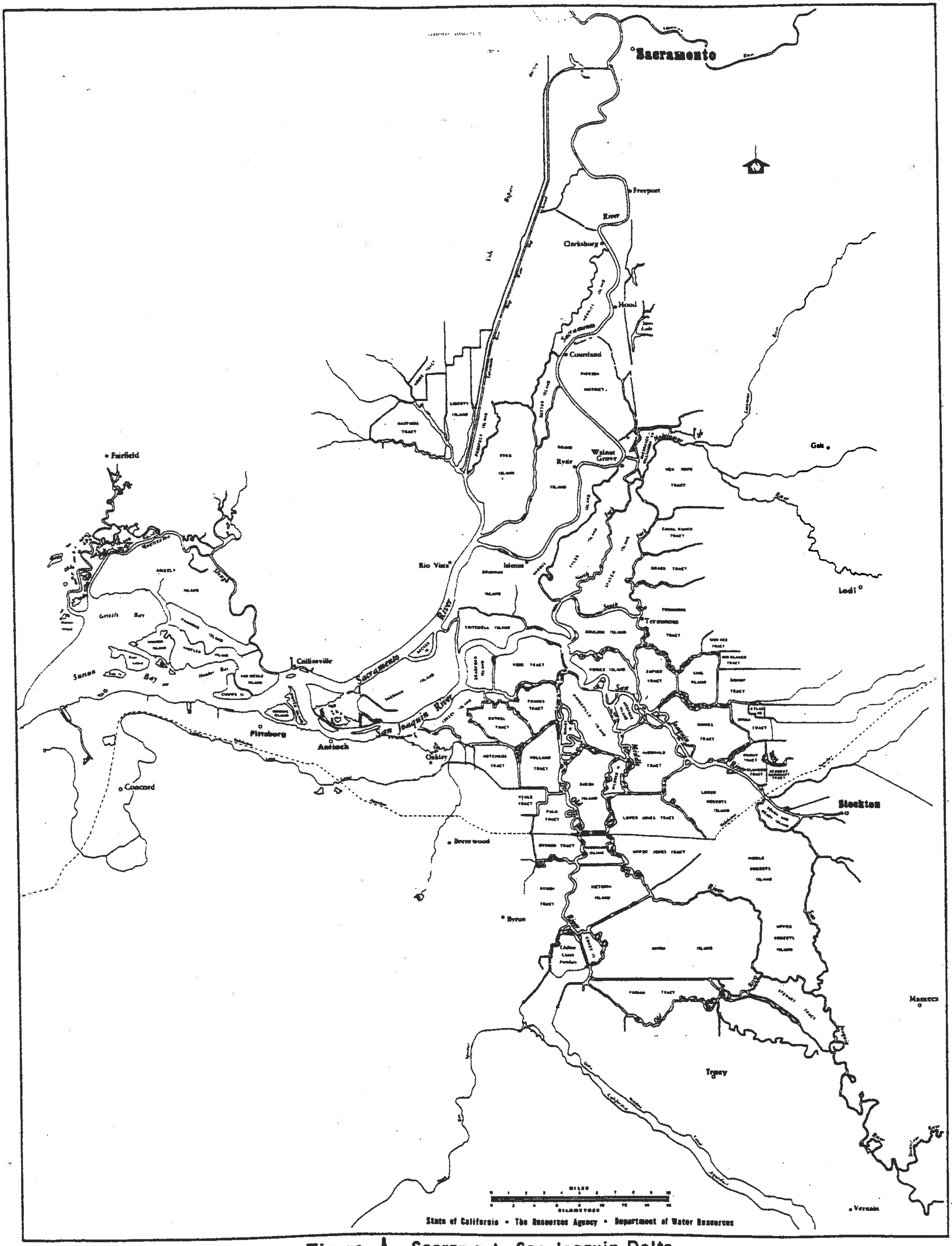


Figure 1. Sacramento-San Joaquin Delta.

background needed to better understand the report. These points deal with the Delta itself as well as the life histories of the striped bass and salmon.

The Sacramento-San Joaquin Delta

From the perspective of this report, the important points to note about the Delta, shown in Figure 1, revolve around its agricultural economy. In terms of water supply, the Delta can be conveniently broken down into two general catagories -- Delta uplands and Delta lowlands.

The Delta lowlands generally lie below an elevation of 5 feet above mean sea level and in some cases the areas inside the levees (the areas enclosed by levees are termed islands in this report) have subsided to as low as 20 feet below mean sea level. Irrigation water is supplied from surrounding surface channels by low lift pumps and siphons, reuse of drainage water, and sub-surface infiltration. Water use within the Delta lowlands has never been measured and is estimated by projecting consumptive use of the various crops grown. Cropping patterns in the region are periodically obtained by interpreting low-level aerial photographs with sufficient ground-truth verification to assure accurate estimates. Delta lowlands consist of approximately 425,000 acres, of which about 385,000 are suitable for agricultural use.

The Delta uplands constitute the area between the lowlands and the legal boundary of the Dleta and generally lie at elevations of +5 feet and greater. Most diversions from surface channels to the Delta uplands are made by pump with additional irrigation supplies coming from wells and diversions from internal drains. There are some data available on amounts of water diverted by pumps; however, the total water use in the uplands is also estimated by the consumptive use method. There are approximately 260,000 acres in the Delta uplands, of which about 185,000 (72 percent) acres are irrigable.

Chinook Salmon

With regard to this report, the important points about chinook salmon relate to how different facets of its life history make migrating fish vulnerable to siphons and pumps that divert irrigation water from the Delta. Spawning runs exist in the Sacramento and San Joaquin systems, although the runs in the Sacramento system are by far numerically greater. Under the assumption that upstream migrating adults are not vulnerable to be diverted by small intakes, the primary concern is with the downstream migrants. Figure 2 shows the time at which downstream migrating juveniles move past Hood on the Sacramento River. Note that fry migration generally occurs in winter and appears to be in response to sudden increases in riverflows. The majority of the smolts migrate downstream in late spring; although some are present during any month of the year. Smolts generally move through the Delta relatively rapidly; however, fry may take up residence in the freshwater portion of the Delta for periods of up to two months (Kjelson, et al, 1981). The migratory patterns described above pertain mainly to wild fish. Superimposed on their distribution is that of hatchery releases. The State hatcheries (Oroville on the Feather and Numbus on the American) release older (yearling) fish near Chipps Island. A release program of this type makes the young salmon less vulnerable to being diverted onto agricultural fields.

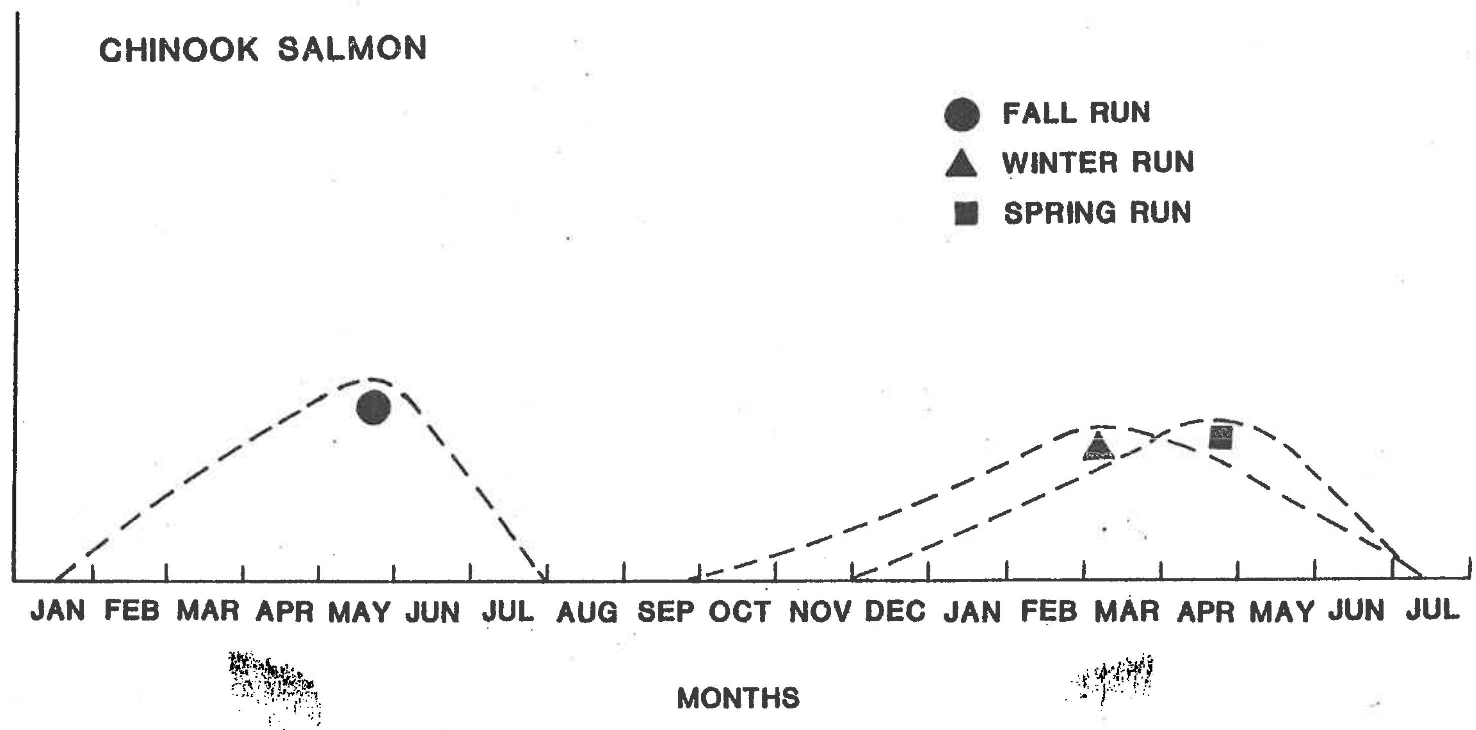


FIGURE 2 SEASONAL OCCURRENCE OF JUVENILE CHINOOK SALMON IN THE SACRAMENTO RIVER NEAR HOOD.

The federal Coleman Hatchery near Redding releases its fish in the upper river. Most of the fish migrating down the Sacramento and San Joaquin Rivers are wild fish.

A complicating factor in assessing a juvenile salmon's chances of being diverted on to farmers' fields within the Delta is the change in migrating patterns associated with cross-Delta flow caused by Federal and State pumping in the south Delta. Fish that would not normally be exposed to agricultural diversions in the interior Delta may become exposed because pumping plants cause the fish to move across the interior Delta with water from the Sacramento River. Some Sacramento River outmigrants may move up the San Joaquin River to the pumps during periods of reverse flow.

Steelhead trout, another important anadromous salmonid which uses Delta waterways in its migrations, can be expected to resemble chinook salmon in the susceptibility of its smolts to being diverted by Delta farmers.

Striped Bass

Striped bass are unlike chinook salmon in that more of their life is spent in or going through the Delta. Adults spawn in the Sacramento and San Joaquin systems in April and May and the buoyant eggs float downstream. As the fertilized eggs move downstream, they undergo embryonic development so that by the time they reach the vicinity of Suisun Bay, they are fully developed larvae ready for first feeding. Important points about the initial developmental stages of the striped bass are that the eggs and initial larval stages are very small (less than 6-7 mm) and are essentially planktonic. The larval bass are concentrated in the western Delta-Suisun Bay by the interaction of fresh and salt water movements (see for example Arthur and Ball, 1978). When they reach the so-called "entrapment zone" the bass are about 7-10 mm total length and remain in this area of high food availability for the next several weeks until they are large enough (typically longer than 38 mm) to effectively forage for themselves. The Delta itself may have been an important nursery for young bass, but its importance may be less since the State and Federal pumps changed flow patterns in the Delta.

DELTA AGRICULTURAL DIVERSIONS

The Delta irrigation season runs generally from late March-early April through September. DWR and the U. S. Bureau of Reclamation (USBR) estimate Delta agricultural diversions by a series of calculations based on such factors as land use, evapotranspiration rates, leach water, precipitation, and soil moisture depletion. Prior to 1980, the results of calculations made independently by both agencies were not in close agreement. Subsequently, an attempt has been made to reconcile the differences; an attempt which culminated in a 1981 report by Lyford, et al. The effort has resulted in calculations of total Delta water use which are in good agreement, although the monthly values calculated by the two methods do not always agree. For purposes of this study on screening agricultural diversions, I averaged the DWR-USBR estimates. These average values provide an idea of the amount of water pumped and siphoned from Delta channels.

Figure 3 contains a plot of the estimated average channel depletion during the 1968-1977 period. The average yearly total is estimated to be slightly more than 1 million acre-feet, with a maximum monthly value in July of almost 300,000 acre-feet. Because of local precipitation patterns, Delta agricultural diversions are minimal or nil during the December through February period.

The data from Figure 3 have been used to obtain the estimates of average monthly diversion rates plotted in Figure 4. During the period of maximum irrigation, or July for the period of analysis, an average of almost 5,000 cubic feet per second (cfs) are diverted from the channels. During the April through August period, when the eggs and/or young of chinook salmon, steelhead, striped bass, and American shad are present total diversions average from 2,500 to about 5,000 cfs or same general range as both the State or Federal intake in the south Delta.

There are no recent descriptions of number, location, and sizes of the individual points of diversion in the Delta. The most recent complete survey of the diversions was by the USBR in 1963 and 1964. The results of its studies were published in a series of reports -- 10 for the lowlands and 13 for the uplands -- which included sections on water rights and ownership, water supply for irrigation, irrigation and drainage facilities, and land use and water requirements. The reports showed the approximate location of the individual intakes but did not provide any descriptive regarding pipe sizes, available head, rated pump capacity, etc. As part of this study on screening, we did conduct a brief survey of Grand, Bacon, and Ryer to obtain some idea of the pipe sizes for both pumps and siphons, and the available head for the siphons. The Bureau reports and our brief survey constitute the basis for the following information on numbers, sizes, and locations for the intakes.

Based on the USBR reports, there were approximately 850 pumps and 1,000 siphon intakes in the Delta uplands and lowlands, for a total of 1,850 diversions. Although the data are relatively old, the total irrigated acreage has not changed appreciably since the early 1960s and it is unlikely that the number of diversions has changed much either. Our surveys of Grand, Bacon, and Ryer indicated that the intake locations on these three islands were about the same as portrayed in the Bureau maps. One change that may have taken place is increased use of sprinkler irrigation today, as compared to 1960, which could change some siphons to pumps to provide the needed pressure.

Figure 5 contains histograms of pipe sizes for pumps and siphons we found on Grand, Bacon, and Ryer Islands during February 1982. In both cases, the modal size was 12 inches; however, the mean size of the pump intakes was (11.2 inches) slightly smaller than for siphons (13.7 inches). The size frequencies are probably typical of other locations throughout the Delta.

The volume of water diverted by pumps and siphons or a given size varies considerably, depending on such factors as lift, pump type, horsepower, pipe type and length for pumps, and available head, pipe material and length for siphons. For a pump with a 12-inch intake and typical conditions found in the Delta, the pump might be expected to deliver in the range of 10-15 cubic feet of water per second. Chuck Wagner (personal communication) estimated a range of flows in 67 diversions in the Delta uplands, Sacramento to the Mokelumne River. His estimates are:

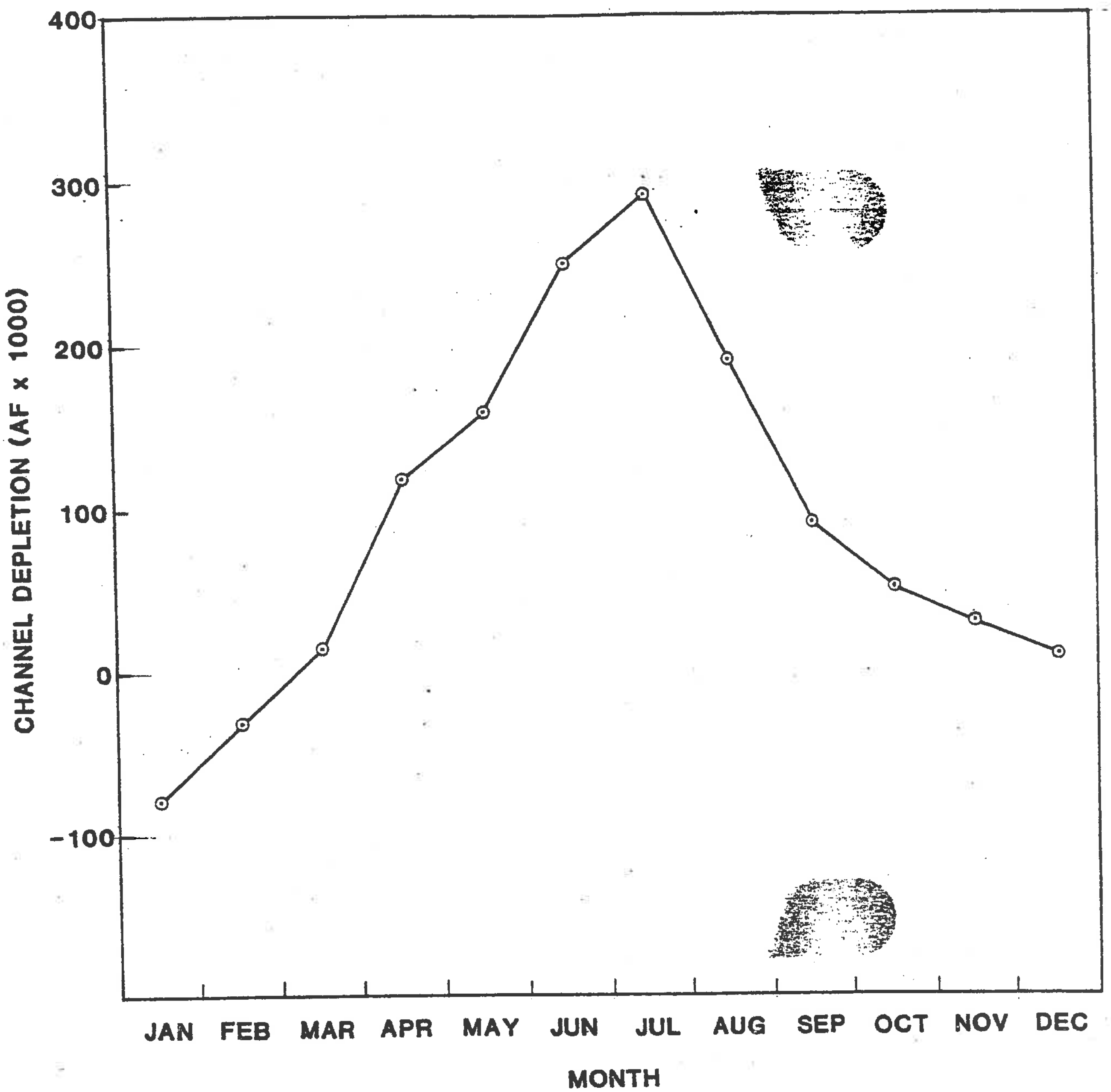


FIGURE 3 AVERAGE MONTHLY CHANNEL DEPLETION IN DELTA SERVICE AREA. (1968-1977 Data using average of USBR and DWR estimates)

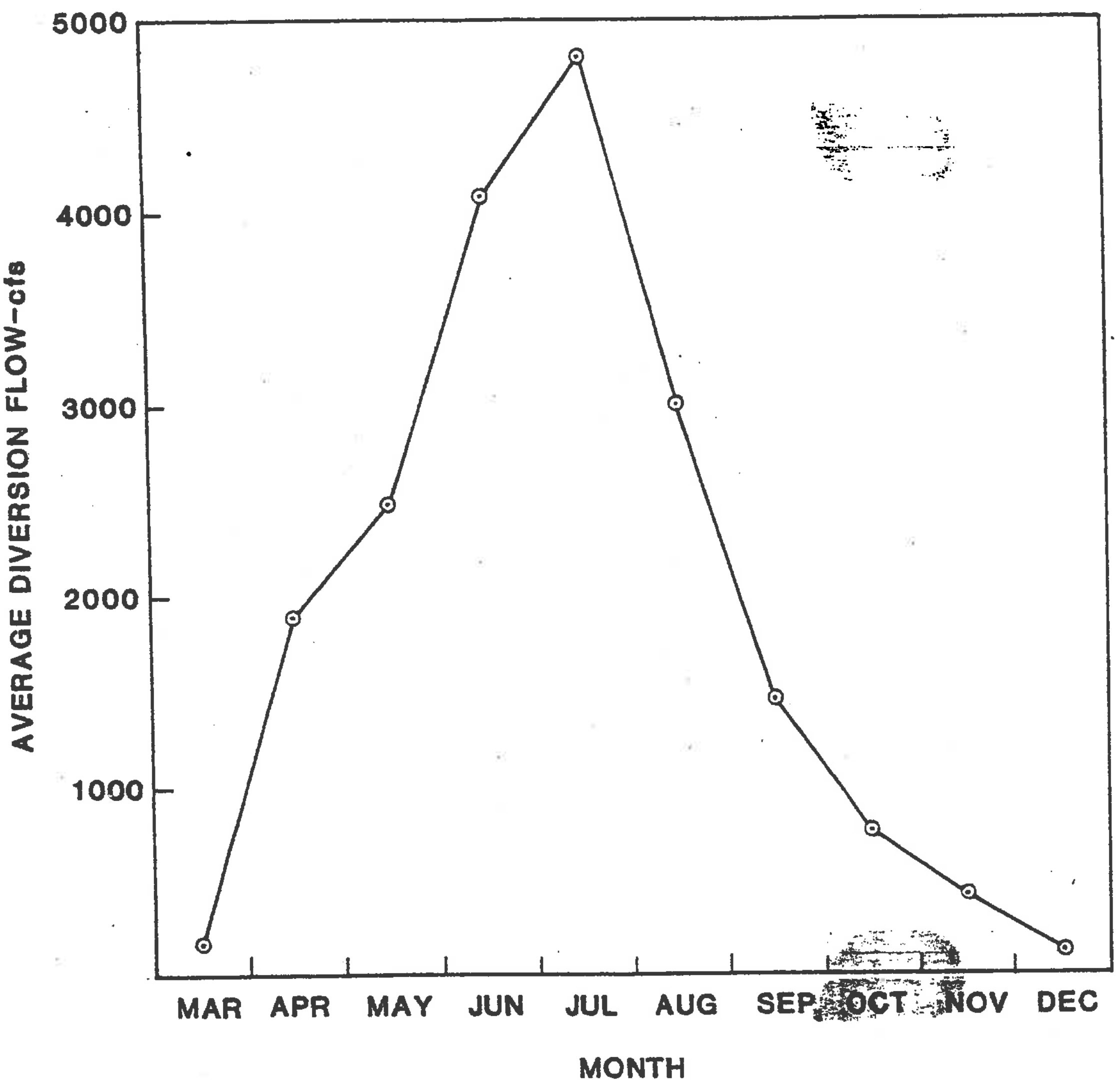


FIGURE 4 ESTIMATED MONTHLY DIVERSION RATES, SACRAMENTO-SAN JOAQUIN DELTA AGRICULTURAL DIVERSIONS, 1968-1977

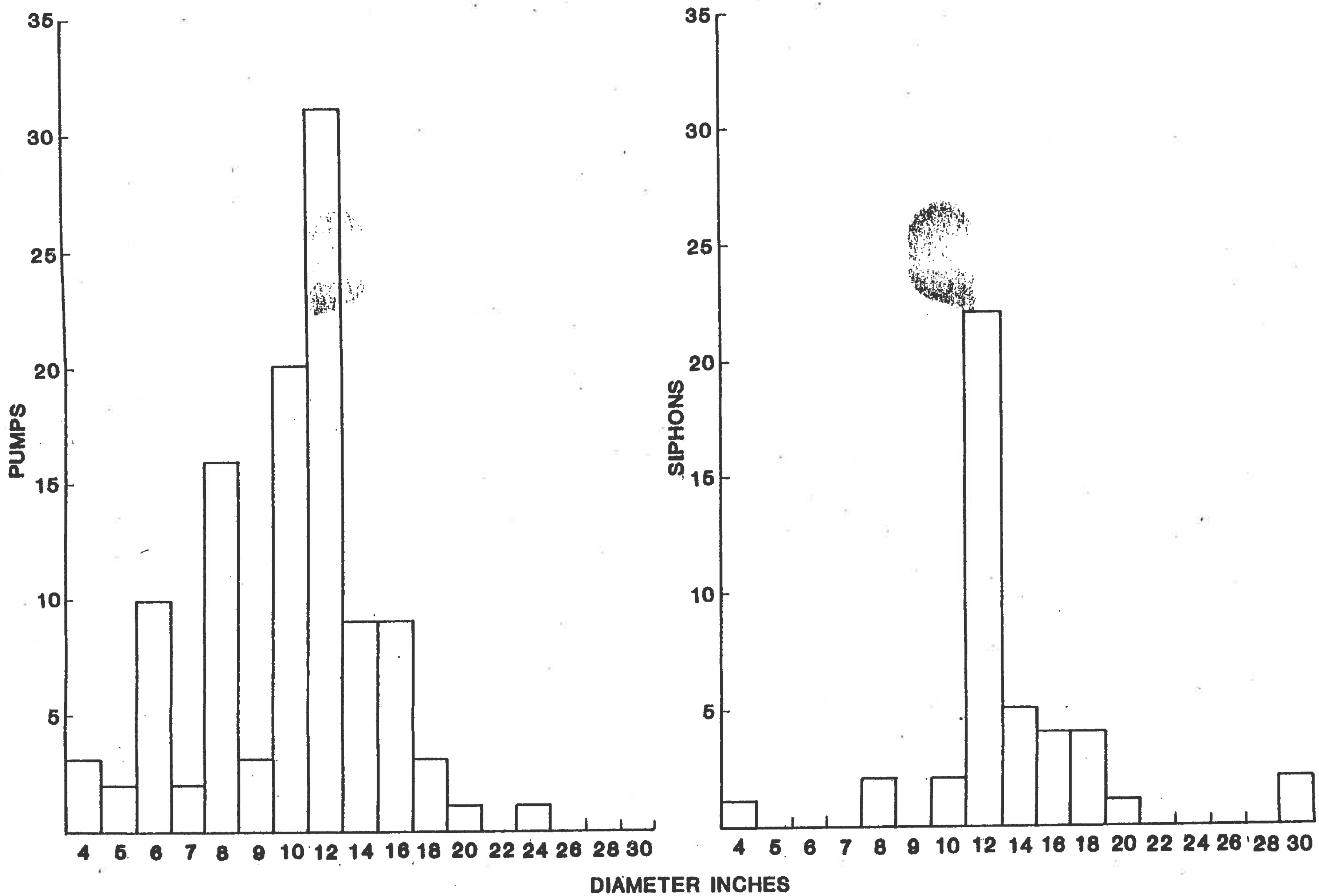


FIGURE 5 PIPE SIZES FOUND FOR AGRICULTURAL DIVERSIONS GRAND, BACON, AND RYER ISLANDS, 1982

0.5 to 5 cfs	57 diversions
5 to 15 cfs	5 diversions
16 to 48 cfs	5 diversions

Based on the above, it appears that most Delta agricultural diversions are fairly small, with maximum flows in the range of 10-15 cfs. Comparing the total average volume pumped in August (about 5,000 cfs) with the estimated numbers of intakes (about 1850), an average flow of 2.70 cfs per diversion is obtained. If the numbers are reasonably correct, this indicates that the diversions operate only intermittently even during peak irrigation season.

LEGAL ASPECTS OF SCREENING

The Office of the Chief Counsel, California Department of Water Resources, researched the question of legal responsibility for screening agricultural diversions in the Sacramento-San Joaquin Delta. The complete text of the legal opinion is attached as an appendix to this report. The results are summarized in this section.

The gist of the legal opinion is that the responsibility to screen existing and future diversions rests with DFG. The State has elected to put into the Fish and Game Code certain provisions on screening diversions which effectively remove screening questions from the realm of common law and place them under administrative law. The importance of this distinction lies in the fact that if the State, local government, or private individuals wish to bring suit against small diverters (under 250 cfs maximum rate of diversion) to install fish screens, the financial burden of such screening falls on DFG. DFG must then determine if fish losses associated with individual diverters warrant the capital and operational expenses associated with the screens.

The specific Fish and Game Code provisions are Articles 3 and 4 of Chapter III, Part 1, of Division 6. Article 3 pertains to diversions of more than 250 cfs and states that DFG is to examine the conduits in question to determine if screening is necessary. If screening is required to protect the resource, then the Department provides the design specifications and pays one-half of the cost. Under Article 4, diversions of less than 250 cfs, the same provisions apply except that the entire cost is paid by DFG.

TECHNICAL ASPECTS OF SCREENING

In the event it were decided to screen agricultural diversions, DFG would provide actual design specifications. Based on experience developed during other screening programs, DFG would require a positive barrier, low approach velocity type of screen. Clogging considerations dictate that some lower limit be placed on the mesh size, and thus the size of fish the screen will protect. Data developed for the Peripheral Canal intake selected about 1 inch as the smallest size fish that could be screened while keeping cleaning within the realm of possibility. Based on salmon and striped bass data, perforated plate with hold diameters of 5/32 inch, on 7/32-inch staggered centers, or profile wire with 3/32-inch slot width will prevent entrainment of fish in the 1-inch size range. It should be noted that it may not be possible to build and maintain screens in the Delta that will prevent the entrainment of striped bass eggs and larvae and will allow the required irrigation flows. Such screening would require mesh sizes on the order of 0.5-1.0 mm and cleaning problems would be severe.

Approach velocity (where approach velocity is defined as the flow divided by screen area) studies for the Peripheral Canal have indicated that velocities of 0.2 feet per second (fps) or lower are required to prevent the impingement and mortality of the most sensitive species tested, juvenile American shad. DFG specified 0.5 fps (maximum) for the screens built to protect the Roaring River intake, Suisun Marsh project, and has indicated that a maximum of 0.5 fps would be acceptable for Delta agricultural diversions (Dan Odenweller, DFG, personal communication).

Another requirement of DFG is that the screen be out in the channel to the extent that there is bypass flow available to move the fish away from the screen. This criterion should not be a problem with typical agricultural diversions in the Delta although there may be a conflict between providing bypass flows and maintaining a navigable channel. Any mid-channel structures would have to permit normal boat traffic. Finally, the maintenance of design approach velocity requires that the screens be kept clean. As holes plug, the velocity through the remaining unplugged holes increases. All screen designs must include a method of cleaning the screens so that head loss is kept to an acceptable minimum and the approach velocity is essentially uniform across the screen face.

From a farmer's standpoint, the design also has to allow for his flow needs even in the event that the screen becomes plugged. Representatives of DFG have indicated that such a failsafe device would be allowed provided that screen cleaning provisions were included in the facility design.

Possible Designs

One of the problems with designing screens of Delta agricultural diversions is the variability of intake sizes, locations, head differential available, availability of power, etc. A few possible designs have been developed and are described below. It should be pointed out that none of these designs has been field tested in the Delta.

Ernie Murphey, retired from DFG's screen shop, developed a design which may be suitable for pumped intakes. The details of the design are sketched in Figures 6, 7, 8, and 9. Essentially, the screen consists of a rotating element on the bottom of an intake pipe which is cleaned by a water jet. Pressure for the water jet is derived from the discharge side of the pump. The drawings show the screen material to be perforated plate; however, welded wedge wire could be used as well. The design incorporates a failsafe device which allows water to be pumped should the screen become clogged.

No scale is shown on the sketches. For an intake with a maximum flow of 30 cfs, it would take 60 ft^2 of screen area which could be achieved by a screen with a diameter of 4 feet and a length of 5 feet. The screen would be submerged to such a depth that, at low water, the pump would not suck air.

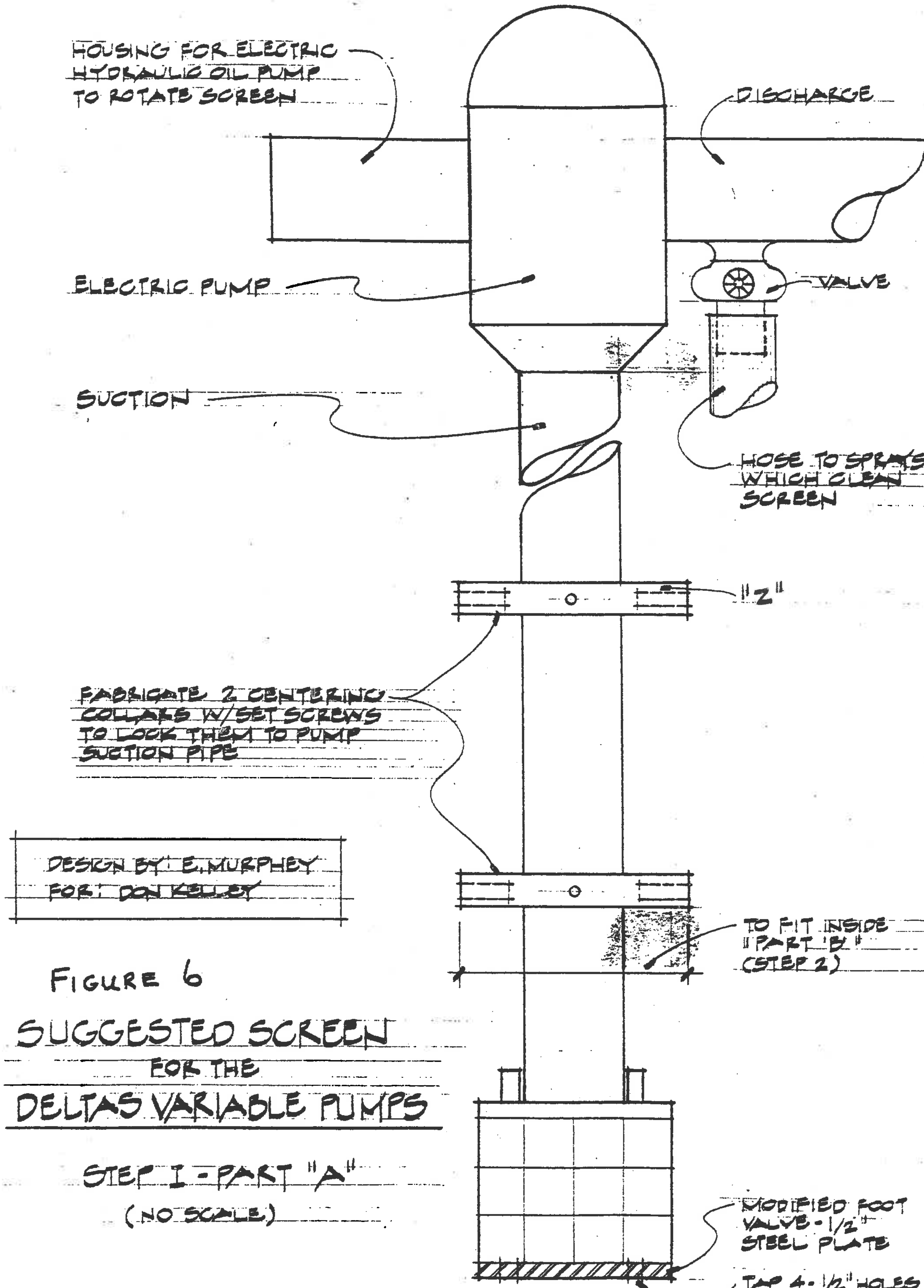


FIGURE 6

SUGGESTED SCREEN
FOR THE
DELTAS VARIABLE PUMPS

STEP I - PART "A"
(NO SCALE)

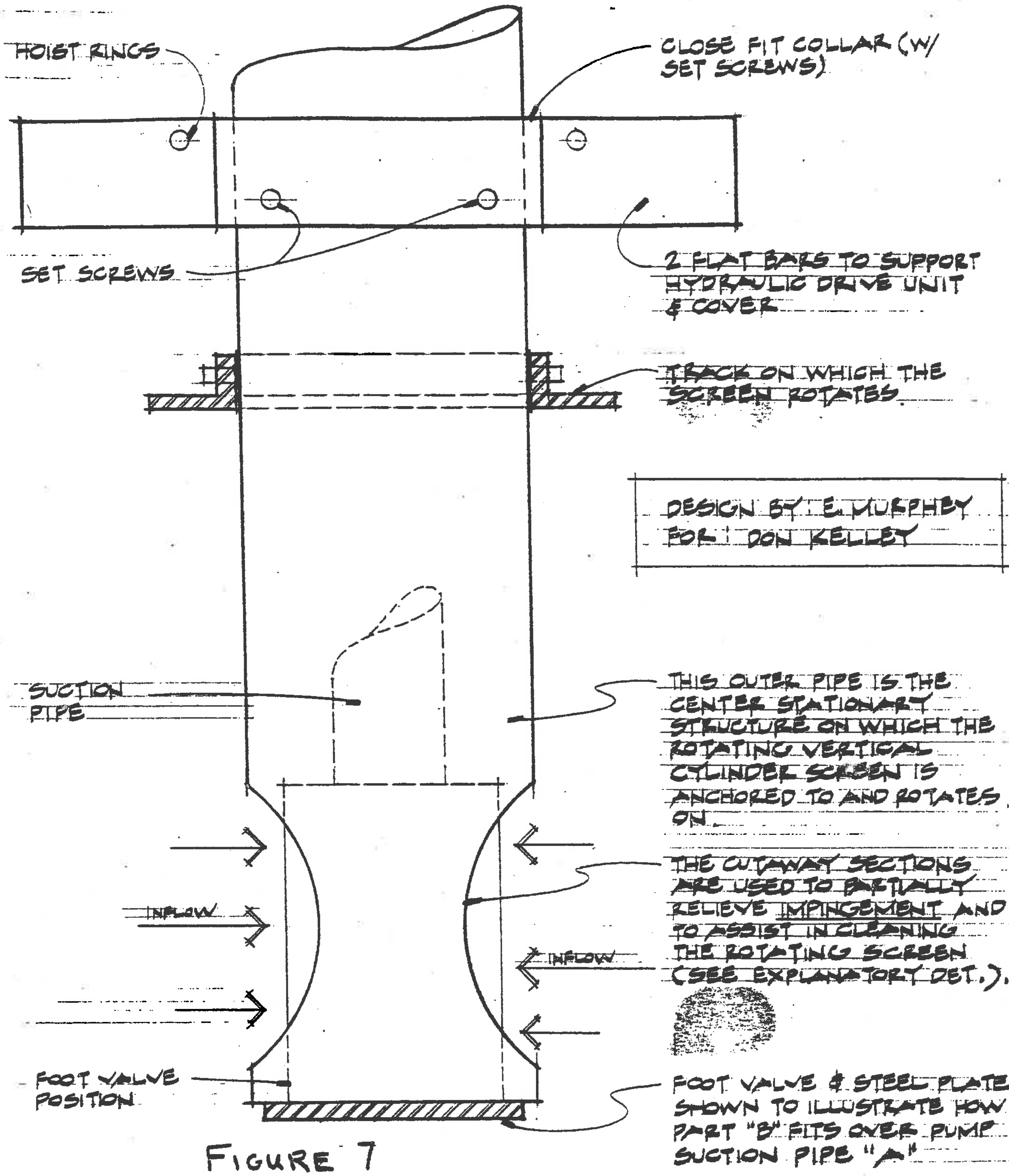


FIGURE 7

SUGGESTED SCREEN
FOR THE
DELTAS VARIABLE PUMPS

STEP II - PART "B"
(NO SCALE)

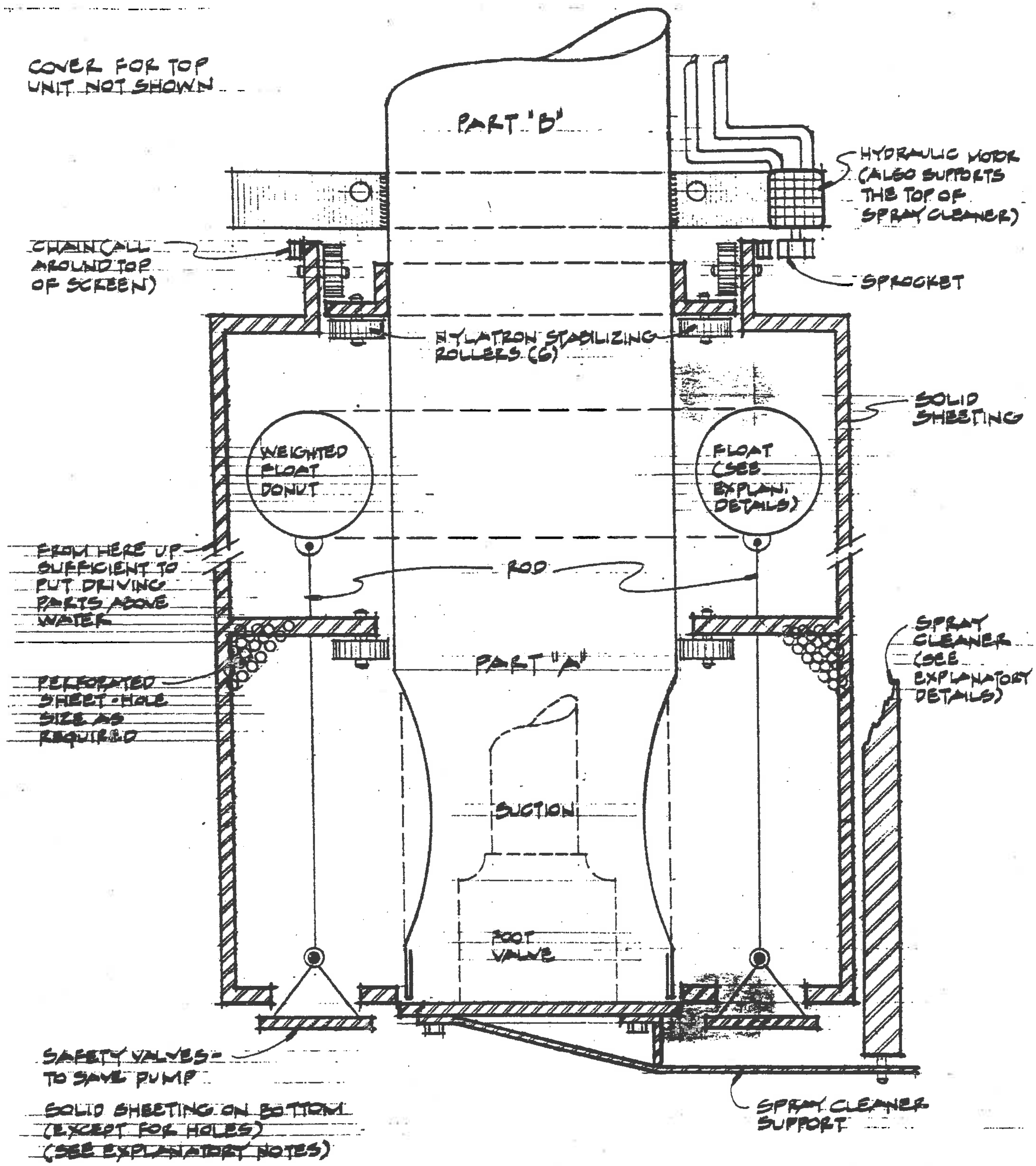


FIGURE 8

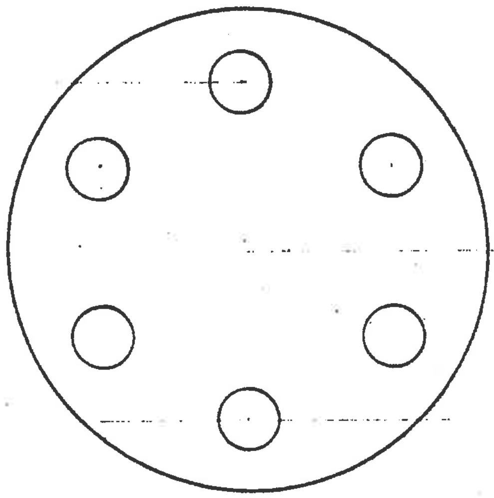
SUGGESTED SCREEN
FOR THE
DELTAS VARIABLE PUMPS

STEP III - PART "C" (THE SCREEN)

FIGURE 1

SUGGESTED SCREEN
FOR THE
DELTAS VARIABLE PUMPS

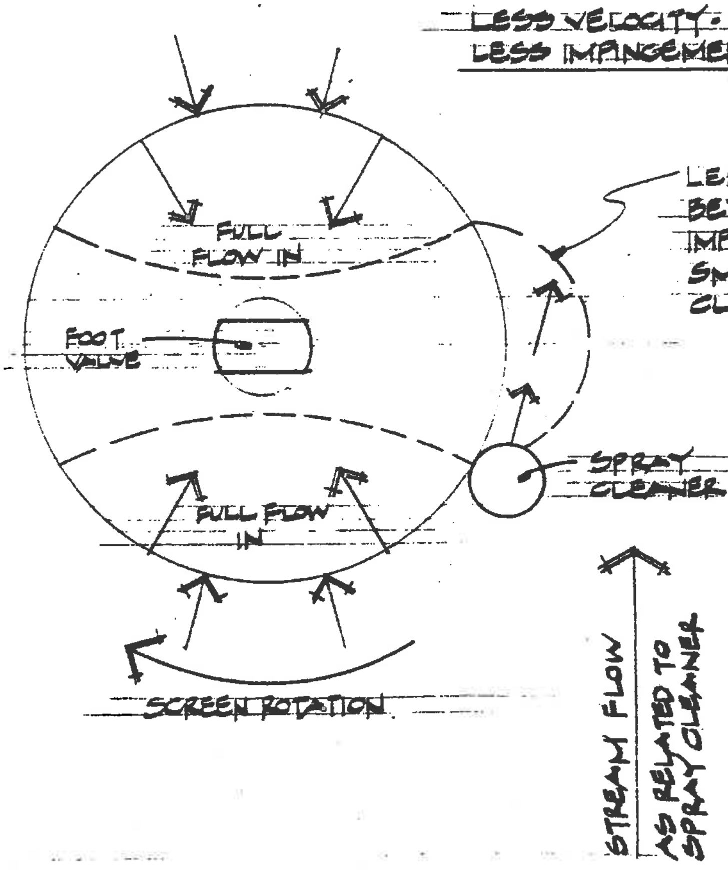
EXPLANATORY DETAILS



THE SOLID BOTTOM WITH SIX (6) ROUND HOLES HELD CLOSED BY THE FLOAT IS A VERY NECESSARY SAFETY FACTOR - BECAUSE - IN CASE OF MECHANICAL FAILURE, THE OPERATING PUMP SOON BURNS UP. BUT, WITH THE ENCLOSED WATER GONE, THE FLOAT LOWERS AND OPENS THE PORTS IN THE BOTTOM SO WATER ENTERS. THE PUMPS KEEP OPERATING. THE FARMER KEEPS IRRIGATING - AND WILLING TO NOTIFY THE MAINTENANCE SHOP.

DESIGN BY: E. MURPHEY
WILSEYVILLE, CA. 95257
FOR: DON KELLEY

LESS VELOCITY - SO - LESS IMPINGEMENT



LESS VELOCITY AREA - ACTUALLY MEANS BETTER & EASIER CLEANING; LESS IMPINGEMENT & GENTLER REMOVAL OF SMALL FISH, EGGS & LARVAE; LESS CLEANING WATER REQUIRED.

NOTES

- ENTIRE ASSEMBLY MAY BE RAISED FOR INSPECTION (OR) REPAIR
- WATER FOR SPRAY CLEANER COMES FROM VALVE ON DISCHARGE
- THE HYDRAULIC PUMP FOR THE DRIVING HYDRAULIC MOTOR COULD BE MOUNTED NEARBY OR ON THE MAIN WATER PUMP

Murphey has also prepared a potential design for a device to screen siphons where no electrical power is readily available to operate a cleaning device. Conceptual diagrams of the shiphon system are found in Figures 10 and 11. Note that the power needed to rotate the cylindrical screen past the cleaning device is derived from the siphon itself. An apparent problem with the system as proposed concerns the possible support (guy lines) needed to keep the receiving water end of the siphon tube vertical. The effect of drawing off head to run the hydraulic motor on flow through the siphon also needs study.

Johnson Division, UOP Inc., manufactures surface water screens in several standard designs. The range of flows which can be screened by standard Johnson intake screens range from about 0.50 cfs to 60 cfs, with the 3/32-inch slot width and a 0.5 fps maximum through-slot velocity. A Johnson Screen with 3/32-inch slot width contains about 50 percent open area; thus, the approach velocity would be about 0.25 fps when the through-slot velocity is 0.5 fps. A Johnson Screen with a 3/32-inch slot and 0.5 fps approach velocity and an intake reated at 15 cfs would have the configuration and dimensions shown in Figure 12. The diameter would be 48 inches, the length 61 inches, and would weigh about 1,000 pounds. A typical installation of a Johnson type cylinder screen is illustrated in Figure 13. Note that the pipe is hinged and a lifting device provided to remove the screen assembly from the water for cleaning.

Single cylinders for larger diversions, 40 cfs, for example, are quite large (72-inch diameter and 89 inches long). The cylinder diameter can be decreased by using a tee-screen (Figure 14). For the same 40 cfs, the tee-screen would have a diameter of 48 inches and an overall length of 161 inches. The reduction in diameter might be important in situations where the water is not deep enough to provide the required 1/2 screen diameter depth between the screen and the minimum water surface and between the screen and the bottom. The minimum clearance is needed to prevent the intake from sucking air at the surface and sucking debris and silt off of the bottom.

Cleaning cylindrical screens can be accomplished by one or more of the following means. Johnson Screens can install a manifold for an air backwash system in which periodically a large burst of air (4-5 screen volumes) is released as close to instantaneously as possible.

Air burst cleaning systems generally consist of a small compressor, and accumulator tank, and a manually or automatically operated quick release valve. Since most siphon locations do not have ready access to power, a variation on the air burst approach is to bring a portable air supply to the site, mounted on a truck or boat, and provide periodic cleaning. Because of the small openings, the expected rapid clogging rate due to peat fibres in the water, and the less than satisfactory results experienced with tests of the system at Hood, it is doubtful that air burst cleaning would be an effective way of maintaining flow through screened siphons in the Delta.

The most apparent effective way to clean the cylindrical screens is by spraying with a high pressure hose. The screens must be pulled completely from the water before spraying and with screens of the general size illustrated in Figure 14 above, the physical system for moving them in and out of the water

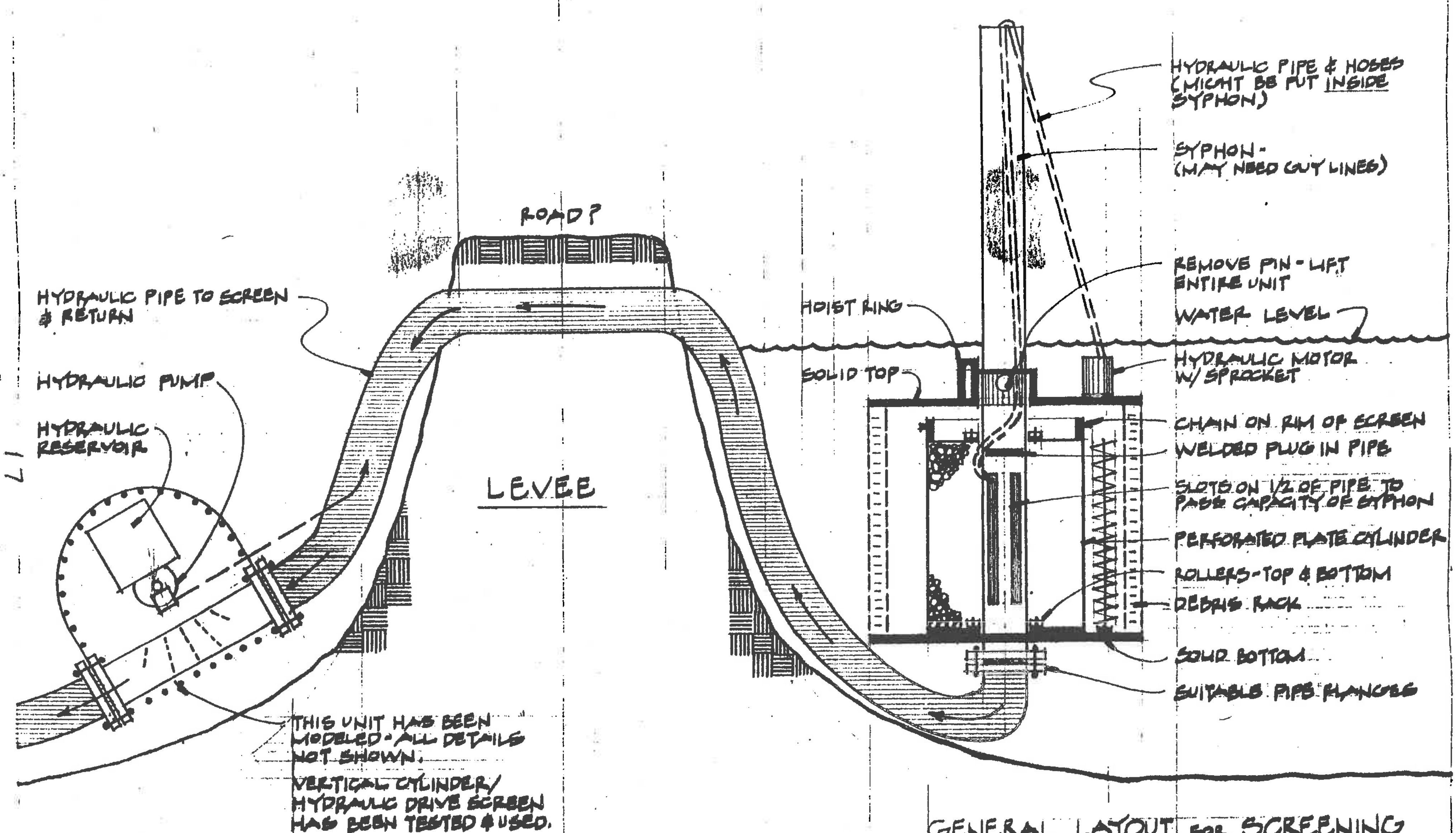
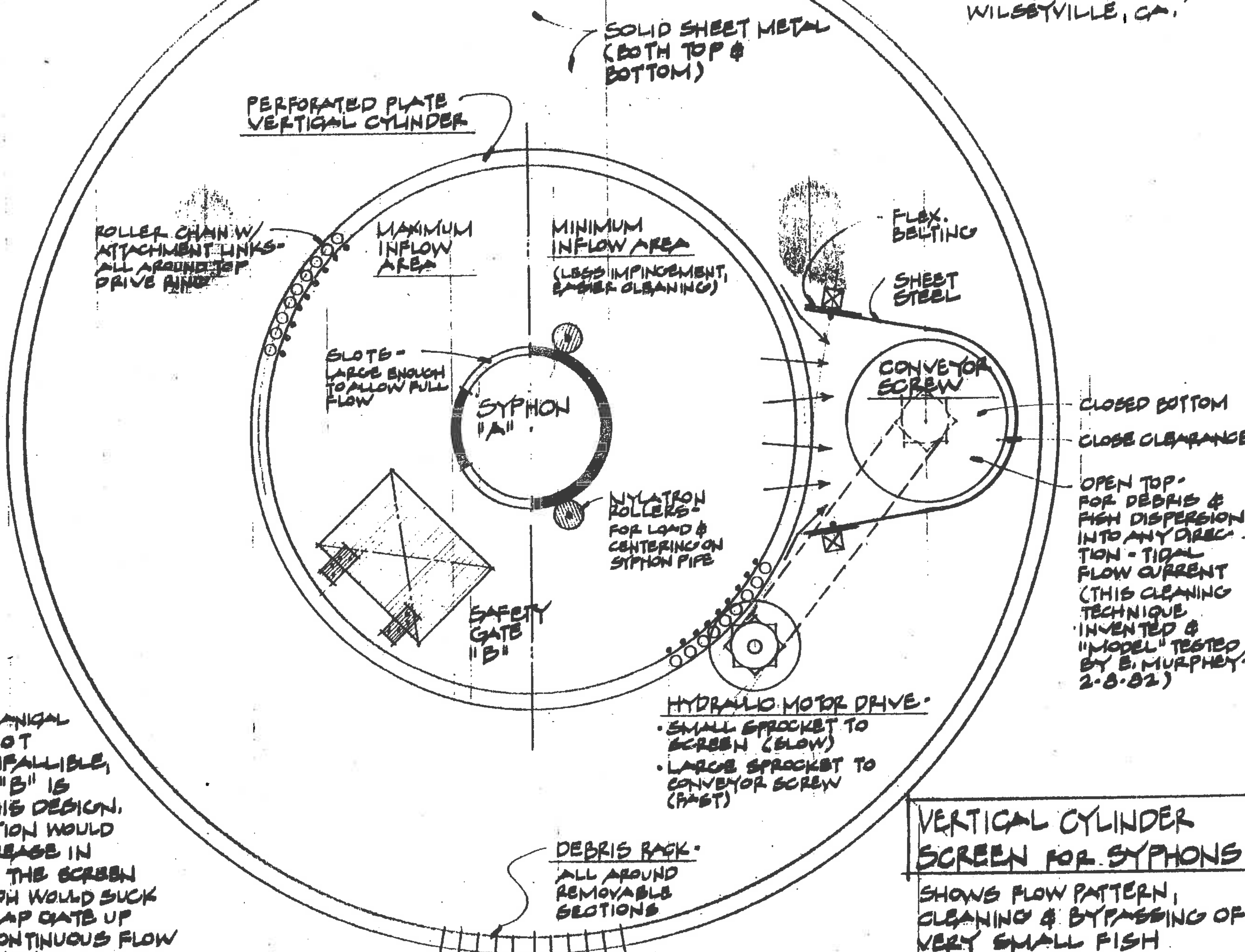


Figure 10 Possible screen design for Delta syphons - general view.

DESIGNED FOR:
DON KELLEY & ASSOCIATES
BY:
B. MURPHEY FEB. 1982
WILSEYVILLE, CA.



NOTE

SINCE ALL MECHANICAL DEVICES ARE NOT ABSOLUTELY INFALLIBLE, SAFETY GATE "B" IS INCLUDED IN THIS DESIGN. ANY MALFUNCTION WOULD CAUSE AN INCREASE IN VACUUM INSIDE THE SCREEN CYLINDER, WHICH WOULD SUCK THE HINGED FLAP GATE UP TO ADMIT A CONTINUOUS FLOW FOR THE SYPHON.

VERTICAL CYLINDER SCREEN FOR SYPHONS

SHOWS FLOW PATTERN, CLEANING & BYPASSING OF VERY SMALL FISH

- NO SCALE -

Figure 11 Possible screen design for Delta pumps - Vertical cylinder screen details.

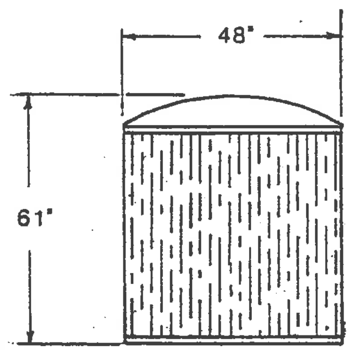


FIGURE 12 STANDARD SINGLE INTAKE SCREENS
LARGE DIA.

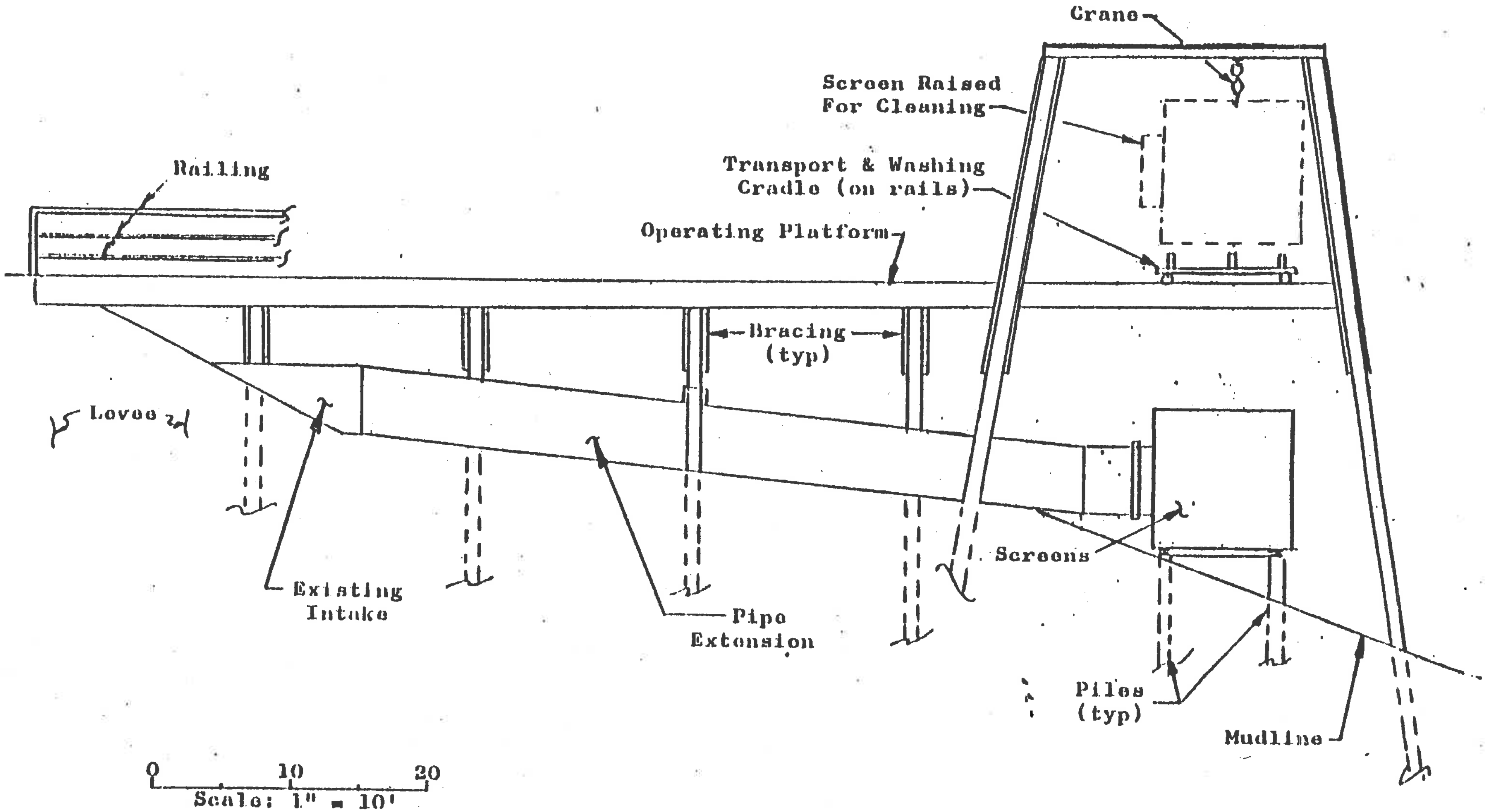


Figure 13 Cylindrical Screen Layout - Profile

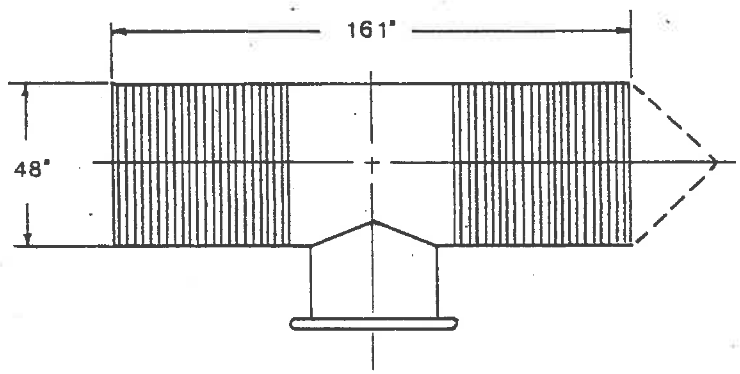


FIGURE 14 STANDARD TEE INTAKE SCREENS

could be fairly elaborate. For most screen locations the spray water would be provided by a water truck or a portable high pressure pump.

Air burst and high pressure water sprays are not particularly effective at removing some attached biological growth. Our experience in the Suisun Marsh has demonstrated that colonial hydroids and barnacles become attached and must be wire-brushed from the screens. The extent of the problem of attached growth on the Delta screens is unknown. Attached growth was not a problem at the Hood site but has been a problem in the Marsh. The Delta is generally intermediate in salinity between Hood and the Marsh, but generally is fresh water. Biofouling problems are most often associated with marine environments, thus Delta installations should be relatively free of biofouling problems. If Johnson cylindrical screens were used, they should have removable end plates so that the screen interior would be readily accessible for cleaning. Fouling organisms can bridge between bars supporting the screen wires and fill the inside of the cylinders. Cylindrical (or other) screens can be constructed of a copper-nickel alloy which is toxic to many fouling organisms and acts to slow the rate of fouling. A panel of this alloy has been ordered for the Marsh screens to determine if it is effective at preventing fouling. Preliminary results of these studies indicate an initial period of growth retardation; however, the copper-nickel screens eventually foul.

Cylindrical screens similar to those built by Johnson could also be constructed from perforated plate. Based on the clogging rate differential between profile wire and perforated plate shown by Smith (1982), and the expected severe clogging problems in the Delta, profile wires would appear to be the material of choice. If the screens remain in the water for long periods, then 304 stainless would be needed. If the screens were submerged only where the farmer diverts, it would be possible to use less expensive material.

Johnson wedge wire can also be built in the form of flat plate and a screen constructed as in Figure 15. This is the type of screen used by DWR in Suisun Marsh. With this screen type there is the advantage of relatively easy access to the screens for observation and clearning. The major problem associated with the screen is poor velocity control which can result in considerable variability in velocities across the screen face. To make this type of screen installation suitable for Delta agricultural diverters would require that some diversions be consolidated and a common point of diversion constructed. It is unlikely that Delta farmers would be receptive to much replumbing of their intake and distribution lines.

FISH LOSSES THROUGH DIVERSIONS

This section contains an attempt to estimate the numbers of striped bass and salmon lost through local agricultural diversion systems in the Sacramento-San Joaquin Delta. Because of the paucity of data available, the estimates are, at best, only in the order of magnitude range.

Striped Bass

In May, June, and July of 1972, DFG sampled seven agricultural diversions on Sherman Island with the objective of obtaining information on the entrainment

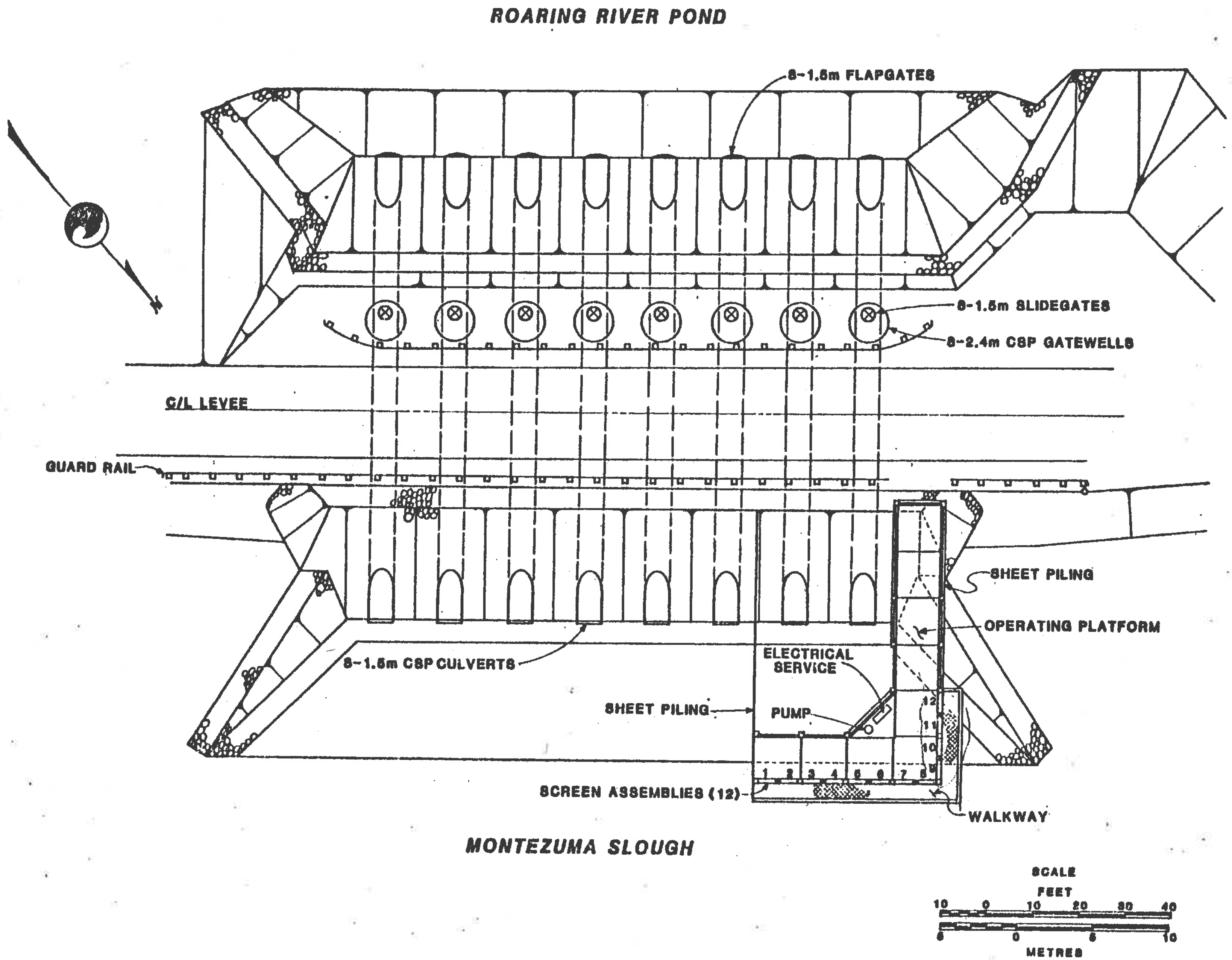


Figure 15. ROARING RIVER INTAKE AND FIRST STAGE FISH SCREEN

of striped bass eggs and young. Samples were also collected in the adjacent channel so that concentrations in the diversion and the source water could be compared. The results of this limited study were described by Allen (1975). The general conclusion reached by Allen was that concentrations in the diversions were statistically identical with those in the adjacent channel. Eggs were present in the river during the period May 3 thourgh June 14 and averaged one per m^3. Peak egg concentrations (in range of .7 - 5.8/m^3) occurred between May 11 and May 19. Striped bass young peaked at 1 - 2/m^3 during the period of May 17 to June 14.

Although the average length of the fish caught in the diversions was statistically the same as that of those caught in the channels, no fish larger than 16 mm was found in the diversion samples. Allen postulated that bass larger than 16 mm could swim well enough to avoid being pulled into the siphons. As well be shown later, 80-100 mm salmon are entrained by siphons. It seems unlikely that 16 mm striped bass can avoid being entrained.

Since the nets used to sample both the siphons and the channel had the same mesh size (nominal mesh opening of 920 micrometres), any sampling bias would have to have been introduced by the water in which the discharge was sampled. Without more data it seems likely that bass greater than 16 mm (to some unknown maximum size) are vulnerable to being entrained in small Delta agricultural diversions.

I made some rough estimates of losses of striped bass eggs and larvae through agricultural diversions for 1978 and 1979. The data bases used in these calculations were from PGandE (1981) and Lyford, et al. (1981). The PGandE report contains tabulations of numbers of bass eggs, yolk sac larvae, larvae, and juveniles in several surveys conducted throughout the Delta in 1978 and 1979. DFG has similar, and more comprehensive, data for earlier years but were not available in a ready-to-use format. The consultant for PGandE (Ecological Analysts) attempted to make their data comparable with those of DFG by using identical (or nearly as identical as possible) field sampling techniques.

The PGandE data on concentations of young bass and eggs were broken down by sampling strata within the Delta. In 1978, the following strata were sampled on 10 sample dates from April 20 through July 10:

Suisun Bay/Carquinez Strait
Upper Bays
Montezuma Slough
Lower San Joaquin River
Lower Sacramento River
Ship Channel/Steamboat Slough
Upper Sacramento River
Upper San Joaquin Delta

In 1979, the number of strata was increased (see below) and the number of sampling dates was increased to 13 between April 18 and July 10. As is apparent from the the number of strata, the Delta was fairly well covered, especially in 1979. Because the diversion data from Lyford, et al., were not broken down by area within the Delta, I simply averaged all egg and larvae data for each month to obtain an overall monthly average Delta bass concentration for each year, excluding those stations where agricultural diversions were not expected (i.e., Montezuma Slough, Napa River, Suisun Bay, etc.) or are not part of the study area. The calculated monthly averages, per size class (numbers/m^3) are tabulated in Table 1.

San Pablo Bay
Napa River
Suisun Bay Shoals
Upper Bays/Suisun Slough
Montezuma Slough
Lower San Joaquin Channel
Low San Joaquin River Shoals
Northern Delta
Southern Delta
Lower Sacramento River Channel
Lower Sacramento Shoals
Ship Channel/Steamboat Slough
Upper Sacramento River

Table 1. Estimated monthly average numbers of striped bass eggs and larvae in the Sacramento-San Joaquin Delta 1978 and 1979. Table developed from data reported by PGandE, 1981.

Month	Eggs	Yolk Sac ($\leq$ 6 mm)	Larvae (7-17 mm)	Juveniles (> 16 mm)
		1978		
April	0.12	0.02	0.003	--
May	0.08	1.02	0.65	--
June	0.04	0.10	0.67	0.03
July	--	0.03	0.03	0.025
		1979		
April	0.01	0.06	0.02	--
May	0.03	1.87	0.34	0.01
June	0.012	0.25	0.18	0.01
July	0.004	0.02	0.01	0.02

A couple of comments about the data seem in order. First, the data are not corrected for any possible bias resulting from the sampling procedures used. If appears that the nets were not effectively sampling striped bass eggs, and perhaps not young bass longer than 16 mm. Egg concentrations, in particular, never approached levels reported by Allen (1975) and Shaffter (MS). Second, the two years were considerably different water years and DFG (letter from Don Stevens to the State Water Resources Control Board dated January 27, 1982) estimated that the numbers of 7-10 mm bass were also different. In 1978, there were an estimated 6.59×10^9 bass, which dropped to about 1.25×10^9 in 1980. Finally, the data used also were collected during the post-1976-1977 period when the numbers of bass were typically much lower than in earlier years.

Lyford, et al., provided information on net channel depletions. I used the average of the USBR and DWR estimates for the 1968-1977 period. The numbers are for the entire Delta and have not been broken down by area. Also, net channel depletion is a function of volume diverted from the channels and drainage water returned to the channels, and during the summer net channel depletion is a smaller number than total water diverted. George Sato (DWR personal communication) estimated that net channel depletion should be multiplied by about 1.25 to obtain total volume pumped during the non-rainfall months. For purposes of these calculations, I used the following net channel depletions and did not correct to water actually diverted.

Month	Depletion, acre-feet
April	110,000
May	150,000
June	239,000
July	290,000

Combining the bass availability data with the average net channel depletions, and assuming the bass are diverted at the same concentration found in the channels (Allen, 1975), the following estimates of bass lost during 1978 and 1979 are obtained (Tables 2 and 3).

Table 2. Number of striped bass life stages estimated to have been diverted by Delta agricultural diversions, 1978.

	Numbers of each life stage lost - millions			
Month	Eggs	Yolk Sac Larvae	Larvae	Juveniles
April	16	3	--	--
May	15	187	119	--
June	12	29	196	9
July		11	11	10
Total	43	230	326	19
			GRAND TOTAL	618

Table 3. Number of striped bass life stages estimated to have been lost through Delta agricultural diversions, 1979.

	Numbers of each life stage lost - millions			
Month	Eggs	Yolk Sac Larvae	Larvae	Juveniles
April	1	8	3	--
May	6	340	62	2
June	3	73	53	3
July	--	7	4	7
Total	10	428	122	12
			GRAND TOTAL	572

These data suggest that the agricultural diversions are cropping large numbers of bass life stages. To put these numbers in perspective, the following estimates of losses of 7-10 mm bass for 1978 are available (Table 4).

Table 4. Numbers of striped bass (7-10 mm) estimated to have been lost to various diversions in the Sacramento-San Joaquin Delta, 1978.

Item	Number	Reference
Total 7-10 mm bass in system	6.59×10^9	DFG, 1982 (1)
Loss to PGandE Plants (range)	$.5-.6 \times 10^9$	DFG, 1982 (2)
Loss to Federal and State Pumps (range)	$.22 \times 10^9$	Sitts, 1982 (3)
Loss to Delta Agricultural Diversions	$.4-.5 \times 10^9$	This report

(1) Letter from DFG to the State Water Resources Control Board, January 29, 1982.
(2) Memo report to State Water Resources Control Board, January 1982, commenting on PGandE's estimates of power plant cropping at their Pittsburg and Contra Costa power plants.
(3) Rick Sitts, personal communication.

From the screening standpoint, the bass being entrained in the agricultural diversions are mostly in the size ranges that cannot be effectively screened with existing technology. Using the criteria developed at Hood (3/32-inch perforated plate) fish less than about 25-30 mm are not screened. To screen the larvae being shown as lost through the agricultural diversions would require mesh openings in the size range of 0.5-1.0 mm.

Chinook Salmon

Estimating losses of young chinook salmon is even more difficult than making similar estimates for striped bass. Except for Hallock and Van Woert (1959) there has not been much work conducted to determine losses of salmon through agricultural diversions. This early DFG study was conducted in 1953-1955 and the results are not particularly relevant to the estimating losses of salmon, mainly because the authors did not quantify losses in terms of fish per volume of water diverted and because the timing of the ocean migration has apparently changed since then.

The discussion which follows is based on data collected during fish salvage operations of the State and Federal pumping plants in the south Delta, a study conducted by the U. S. Fish and Wildlife Service (USFWS) and DFG, and some data on fish occurrence and distribution reported by Shaffter, 1980.

During the May-June period of 1976, DFS and USFWS conducted a limited study of the losses of chinook salmon through six agricultural diversions on Grand and Sherman Islands. The results of this study were never published; however, there are some unpublished notes with brief descriptions of the methods and results. The following material was extracted from those notes.

The six water intakes included five individual siphons (20, 30, 18, 14, and 20 inches in diameter) and one combined intake consisting of two 18-inch siphons and one pump with an intake pipe 14 inches in diameter. The notes listed average flow rates for each intake, although no indication was given as to how these flow rates were determine or over what period the flows were averaged. The flow rates were 10, 19, 4, 6, and 14 cfs for the intakes listed above.

Fyke nets with live boxes were used to sample the discharges. Analysis of the data is complicated somewhat by the fact that the investigators used three different nets to capture the fish. The first net had stretched mesh sizes varying from 1/2 inch to 1-1/2 inches. Next, a net with a uniform 1/2-inch stretched mesh was experimented with. Finally, a net with 1/4-inch stretched mesh was experimented with.

Each net had a different efficiency at capturing salmonids. To estimate net efficiency, marked chinook fingerlings were released into the discharge in front of the net. Efficiencies tabulated below are from individual tests at each siphon and were obtained with releases of approximately 50 chinook salmon during each test.

Net Efficiency (% Captured) of Three Net Types

	Net	
Variable Mesh	1/4 Inch	1/8 Inch
22	25	100
60	85	
27	17	
66	29	
85	50	
8	58	
38	52	
$\bar{x}$ = 43.7	45.1	100
s = 27.5	23.4	

As the above data indicate, the capture efficiency was extremely variable. For the two most commonly used nets capture efficiency appraently averaged about 50 percent.

A 1/8-inch mesh beach seine was used to determine if the fish caught in the fyke nets were the same size as those in the river. At one location on Sherman Island, a total of 58 fish was caught with the seine and the fish averaged 80.2 mm (standard deviation of 6.6 mm). The 56 fish caught in the fyke nets during the same period averaged 81.5 mm, with a standard deviation of 7.6 mm. These data indicate that the two gear types caught fish of essentially the same size.

The catch data are summarized in Table 5, along with estimates of losses of salmon per acre-foot of water diverted at these intakes during the months of May and June 1976. These data can be extrapolated to the entire Delta by assuming that the fish/acre-foot data also hold for April and July and using the estimated diversion rates for the Delta. The results of these calculations are:

Month	Ac-Ft Diverted	Fish/Ac-Ft	Fish Diverted
April	110,000	0.09	9,900
May	150,000	0.09	13,500
June	239,000	0.09	21,510
July	290,000	0.09	26,100
		TRAND TOTAL	71,010

The estimate of 71,000 fish lost is so low in relation to the millions of young salmon passing through and around the Delta that there are immediate questions about its validity. Other data were examined to determine if the number could be supported or refuted.

Table 5. Estimated numbers of chinook salmon trapped in six agricultural diversions -- San Francisco-San Joaquin Delta, 1976.

	Diversion No.					
	1	2	3	4	5	6
No. of fish caught (1)	152	28	30	66	0	0
Average flows, cfs	10	19	4	6	14	10
Numbers of hours fished	1,196	621	713	1,012	575	430
Total ac-ft sampled (2)	984	971	235	500	662	354
Fish/ac-ft	0.15	0.03	0.13	0.13	0	0.02
					$\bar{x}$ =	0.09 (3)

(1) Numbers corrected for net efficiency. Efficiency of 50 percent was assumed.
(2) Based on average flow and number of hours fished.
(3) Does not include 0 catch.

The most complete set of entrainment data for the Delta area comes from the State and Federal water projects which divert from the south Delta near the towns of Byron and Tracy, respectively. Figure 1b contains plots of the average number of chinook salmon salvaged at the two fish protection facilities for each month during the 1968-1980 period. These salvage values, which because of screen efficiency probably only represent 70-80 percent of the salmon entrained, are somewhat higher than reported for the diversions sampled by DFG and USFWS in 1976, but still the same order of magnitude. It should be noted that both sets of data suffer from a similar deficiency in that the estimates were made in areas where one would not, a priori, expect high concentrations of salmon smolts. In both cases, the use of these estimates should result in entrainment losses that are biased low. Using average federal salvage (somwhat higher than similar values for the State facility) for April through July for the 1968-1980 period and the volume of water estimated diverted by Delta agriculture, the following estimates for the entire Delta are derived:

Month	Ac-Ft Diverted	Fish/Ac-Ft	Fish Diverted
April	110,000	0.28	30,800
May	150,000	0.37	55,000
June	239,000	0.11	26,290
July	290,000	0.003	870
		GRAND TOTAL	112,960

Although the use of the salvage values increases the estimated losses over those from the 1976 data above, still the total numbers of fish estimated lost are very small. The last piece of data that seemed applicable was from the fish occurrence and distribution study conducted near Hood in 1973-1974 by DFG (as reported by Shaffter, 1980). In 1973 and 1974, approximate catches of chinook salmon per acre-foot of water sampled by midwater trawl were:

Month	1973 Fish/Ac-Ft	1974 Fish/Ac-Ft
April	4	1
May	4	5
June	1	1
July	1	5

If fish were diverted according to flow in the Sacramento Fiver the fish/ac-ft figures would suggest high diversion losses in this part of the system. We have no information on how a 70-80 mm salmon reacts to a siphon intake, but certainly not all fish coming down the Sacramento River and approaching an intake are entrained. A 12-inch diameter siphon delivering 15 cfs of water – flow actually 7.5 cfs [illegible] would have an in-pipe velocity of about 3 fps. The velocity field around the end of a pipe is unique for each specific configuration; however, at two pipe diameters from the end the velocities will be very slow. Strong swimmers like salmon smolts should be able to avoid being entrained. PGandE (1981) estimated that in 1978 only about 18,000 smolts were entrained in the cooling water intake to their Pittsburg power plant. The relatively small losses were

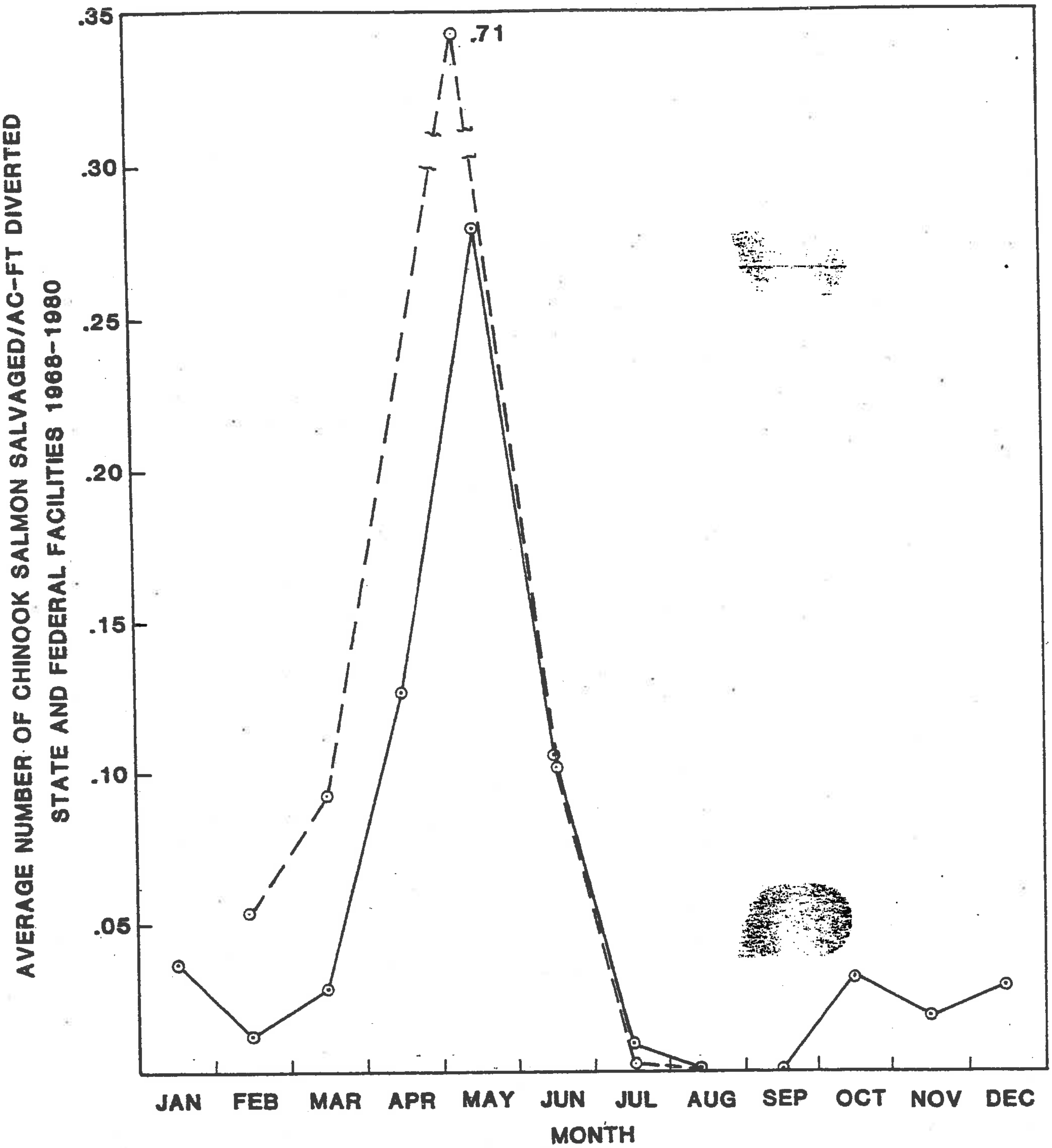


FIGURE 16 AVERAGE NUMBER OF CHINOOK SALMON DIVERTED, FISH/AC-FT, STATE AND FEDERAL FACILITIES, 1968-1980

attributed to ability of the downstream migrating juveniles to actively avoid the intake.

If the numbers of salmon entrained in Delta agricultural divresion is in the magnitude of a few hundreds of thousands, as indicated by the calculations, the benefits of screening these diversions to chinook salmon populations would be low. The same degree of protection for hatchery fish could be achieved by slightly increasing hatchery production or by trucking more salmon for release in the western Delta. Given the technical and economic problems associated with screening numerous small diverions, the above alternatives would be a cost-effective way of getting more hatchery smolts to the ocean.

Increased hatchery operations do little to enhance natural salmon production, although some straying of hatchery fish may result in mixing of the gene pool between hatchery and wild populations. Screening could help maintain wild populations by eliminating losses through diversions. DFG is already planning to, or has, screened major diversions on the Sacramento River. Instead of screening Delta diversions, protection of wild fish might better be achieved by making some of the present screens more effective (for example, Glenn-Colusa) and/or collecting the bypassed fish for trucking to the western Delta for release.

Other Species

As might be expected, there is practically no information on losses of species other than chinook salmon and striped bass in Delta agricultural diversions. The State Water Project diversion near Byron has entrained at least 43 species of fish with an average of about eight fish per acre-foot during the 1968-1980 period (California Department of Fish and Game, 1951). Of these 43 species, five species accounted for 96 percent of the total number of fish collected: striped bass, 62 percent; threadfin shad, 16 percent; white catfish, 7 percent; American shad, 7 percent; and Delta smelt, 4 percent. None of the species entrained was on the rare and endangered species list.

In their 1976 study of six intakes on Grand, Sherman, and Ryer Islands, the U. S. Fish and Wildlife Service and the California Department of Fish and Game collected several species of fish in addition to chinook salmon and striped bass (Table 6). In this study, five species made up 90 percent of the catch; white catfish, 52 percent; longfin smelt, 18 percent; Sacramento hitch, 8 percent; tule perch, 8 percent; and green sunfish, 4 percent. Note that the dominant species collected in these intakes are much different than for Byron, probably reflecting the different location in the system, the particular season these intakes were sampled, and perhaps the difference between a particular water year and a 13-year average. The overall average number of fish diverted in these six siphons and pumps was about 0.5 fish per acre-foot. This average, uncorrected for net efficiency, is much lower than the 8.4 average for Byron. Without more data it is impossible to determine if there is a valid difference or simply an artifact of sampling method and timing. Based on intuition alone, one would expect a large diversion to entrain more fish than a small diversion because, at times, all flow in channels leading to the diversion end up being diverted. The agricultural diversion study did collect two species, the river lamprey and Pacific staghorn sculpin, not collected at Byron.

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Table 6. Summary of fish collected at Ryer, Grand, and Sherman Islands, 1976. From the unpublished notes of a Department of Fish and Game—U. S. Fish and Wildlife study.

SPECIES		NUMBERS/SITE					
		Ryer Island				Grand	Sherman
Common Name	Scientific Name	1	2	3	4	Is.	Is.
Pacific lamprey	Entosphenus tridentatus	2	--	10	4	3	4
river lamprey	Lampetra ayressii	3	2	--	1	1	--
American shad	Alosa sapidissima	--	--	1	4	--	2
threadfin shad	Dorsoma petenense	--	--	3	--	--	7
longfin smelt	Spirinchus thaleichthys	8	68	17	4	--	183
chinook salmon	Oncorhynchus tshawytscha	164	14	32	16	--	4
steelhead trout	Salmo gairdnerii gairdnerii	1	--	1	--	--	--
carp	Cyprinius carpio	21	--	6	--	--	--
goldfish	Carassius auratus	5	3	11	--	--	--
Sacramento blackfish	Orthodon microlepidotus	--	6 1/	--	--	--	--
Sacramento hitch	Lavinia exilicauda	8	16 2/	4	--	93	--
Sacramento squawfish	Ptychocheilus grandis	17	23	5	--	1	--
White catfish	Ictalurus catus	143	225	271	66	24	96
channel catfish	Ictalurus punctatus	--	--	1	--	--	--
yellow bullhead	Ictalurus natalis	--	--	--	2	--	--
mosquito fish	Gambusia affinis	--	--	2	--	--	--
starry flounder	Platichthys stellata	--	--	--	--	--	1
striped bass	Morone saxatilis	1	1	2	--	--	--

Table 6. (continued)

SPECIES		NUMBERS/SITE					
		Ryer Island				Grand Is.	Sherman Is.
Common Name	Scientific Name	1	2	3	4		
largemouth bass	Micropterus salmoides	1	--	--	--	--	--
smallmouth bass	Micropterus dolomieui	--	1 3/	--	--	--	--
green sunfish	Lepomis cyanellus	23	20 4/	16	--	3	2
bluegill	Lepomis macrochirus	--	1 5/	--	--	--	--
black crappie	Pomoxis nigromaculatus	2	--	--	1	--	--
log perch	Percinia caprodes	2	4 6/	3	--	--	--
tule perch	Hysterocarpus traskii	43	13	40	21	4	--
Pacific staghorn sculpin	Leptocottus armatus	--	3	1	3	1	6

1/ 2 taken with electro-shocker.
2/ 9 taken with electro-shocker.
3/ 1 taken with electro-shocker.
4/ 7 taken with electro-shocker.
5/ 1 taken with electro-shocker.
6/ 2 taken with electro-shocker.

Allen (1975) also sampled agricultural diversions in the spring and early summer. Perhaps because the study was designed to capture eggs and larvae, Allen captured only three kinds of fish other than striped bass. There may have been several species involved since the fish were listed only as smelt, shad, and catfish. A total of 19 fish other than striped bass was collected during this study.

COST OF SCREENING

As with most sections of this report there is very little to go on when trying to determine the potential cost of screening the agricultural diversions. Screening costs have three major components. First, there is a cost associated with modifying the diversion so that it can accept a screen. In general, pump diversions would be easier to modify for screening than would siphons. Many siphons are simply pipes through the levee and angled into the water. The heavy weight of the screen would require that the pipe be supported. In many instances the pipe itself might need replacing with a heavier material. The costs associated with this portion of the screening would be site specific and cannot be estimated.

The second screening cost is that of the screen assembly itself and any associated cleaning mechanism. We have no information on the two screen designs by Ernie Murphey; however, Johnson Division, UOP Corporation, does have some fairly specific information regarding its screens. For estimating purposes, the following numbers were provided by the company on December 4, 1981 (dollars/cfs):

CFS Diverted	Standard Single Screen	Standard Tee Screen
1-5	1,240	2,050
6-12	1,050	1,170
13-33	860	1,140

The screens for which the above numbers apply are wedge-wire with 3/32-inch slots, an average through slot velocity of 0.5 ft/sec and constructed of 304 stainless steel. Using these criteria, a square foot of screen will pass 0.28 cfs of water. The quoted costs do not include any cleaning equipment such as air compressors, air accumulators, or air delivery systems. The screen costs would double if copper-nickel alloys were used in screen construction to minimize fouling by plant and animal growth. If the average Delta farmer diverts a maximum of 10 cfs at each site, the screen itself would cost about $10,000-$15,000. With approximately 2,000 locations to screen in the Delta, costs for the screens might be in the order of 20 to 30 million dollars. There might be another $5,000 per site for adapting the intakes to accept the screens which would add 10 million dollars to the screening systems.

The final cost aspect of screening is those costs associated with operation and maintenance of screens (i.e. periodic cleaning, replacement of screen components, seasonal installation and removal charges, etc.). About the only idea we have regarding these costs comes from Dan Odenweller (personal communication), DFG, who reported that one of their screen shops spend $250,000 per year to maintain 12 screens. Certainly $20,000 per year appears to be excessive when applied to Delta screens; however, we might be talking a few thousand per screen per year and spread over 2,000 screens the total per year quickly enters into the millions of dollars per year range. The initial costs of stainless steel wedge wire screens is high relative to other screen types and materials but might be cheaper in the long run because of lower operation and maintenance costs (clog more slowly and the screen material should last indefinitely).

The overall impression which might be obtained from the above discussion is that screening Delta agricultural diversions would be a costly process. If such a program were undertaken, it is highly unlikely that all, or even most, diversions would be screened. The total program costs could thus be reduced significantly. Without more data on the impact of specific diversions on specific fish populations, it is not possible to assign a realistic cost estimate to a Delta screening program.

SUMMARY

1. There are about 1,900 agricultural diversions in the Sacramento-San Joaquin Delta which, during the irrigation season, collectively divert from 2,000 to 5,000 cubic feet per second (cfs) of water from Delta channels.

2. The peak diversion season, April through August, in the Delta coincides with the months when large numbers of young chinook salmon, striped bass, American shad and other fish are present in the system. ?

3. There are very few data available on the losses of resident and migratory fishes as a result of agricultural diversions. Some very rough estimates indicate that the losses of young bass (generally less than 16 millimetres (mm) in length) is in the order of several hundred million and the loss of chinook salmon may be in the range of a few hundred thousand. Data on other species are essentially absent.

4. The technical feasibility of screening diversions to meet salmon criteria in the Delta (0.5 fps maximum approach velocity and 5/32-inch openings for perforated pipe) has not been demonstrated. Screening to salmon criteria would not prevent the entrainment of most striped bass now lost to agricultural diversions, but should protect juvenile American shad, especially during daylight hours.

5. The potential costs associated with screening Delta diversions are largely unknown; however, it will probably cost several thousand dollars per intake (average maximum flow of about 10 cfs) to purchase and install a screen. In addition, there will be operation and maintenance costs in seasonally installing and removing the screens, keeping them clean, and maintaining the structural integrity of the intake and screen.

6. Practially all agricultural diversions in the Delta have flows less than 250 cfs. If the California Department of Fish and Game (DFG) determines that the diversions are having an adverse impact on fishery resources, and that screening would minimize or eliminate that impact, DFG is required to pay for all screening costs.

RECOMMENDATIONS AND RATIONALE

1. Delta agricultural diversions should not be screened at this time. Points leading to this recommendation are:

   a. Available data indicate that losses of striped bass due to entrainment in Delta agricultural diversions are in ~~lift~~ life stages that cannot be easily screened. Losses of juvenile (> 16 mm) bass are largely unknown and may be low because of their ability to avoid being entrained in small intakes.

   b. Available data indicate that losses of juvenile chinook salmon due to entrainment in Delta agricultural diversions are relatively low. There are methods other than screening to mitigate losses of both wild and hatchery salmon.

   c. DFS has established a priority list for screening major diversions (> 250 cfs) on the Sacramento River and would be financially hard pressed to undertake any additional screening projects.

   d. The technical feasibility of effectively screening large numbers of small intakes in an aquatic environment such as found in the Sacramento-San Joaquin Delta has yet to be demonstrated.

2. The most effective way to minimize losses of young bass to agricultural diversions would be voluntary curtailment for short periods in May and June.

3. In recognition of the distinct possibility that measures may be required to restore fish populations, certain concepts should be agreed on and programs established regarding screening Delta agricultural diversions.

   a. The Department of Water Resources (DWR) and the water contractors should accept screening agricultural diversions as a potential mitigation measure for project impacts, in concept no different than hatcheries and operational measures. Under this concept, screening costs would be paid entirely by DWR. Screening could be an important step in maintaining wild populations of resident and migratory fishes.

   b. More work is needed on the technical aspects of screening small diversions in the Delta. One place to start might be to construct models of the two Murphey Screens and test them at Hood for mechanical operation. If the devices operate as designed, then they could be field-tested at a suitable location (near the cross channel at the new pump facility?). If preventing the entrainment of striped bass is deemed necessary, consideration should be given to use of small mesh (0.5-1.0 mm) and only screen for the relatively short period when the largest numbers of bass are vulnerable to entrainment.

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LOSS OF STRIPED BASS (MORONE SAXATILIS) EGGS AND YOUNG THROUGH SMALL, AGRICULTURAL DIVERSIONS IN THE SACRAMENTO-SAN JOAQUIN DELTA[1]

by

David H. Allen
Bay-Delta Fishery Project

ABSTRACT

A sampling program was initiated in the spring of 1972 to obtain information on the losses of striped bass eggs and young through the small, agricultural diversions found throughout the Sacramento-San Joaquin Delta.

Seven agricultural diversions on Sherman Island, adjacent to the San Joaquin River, were sampled on an intermittent basis during May, June and July.

Comparisons between catches from the agricultural diversions and catches from the adjacent San Joaquin River indicated that concentrations of striped bass eggs and young diverted were of the same general magnitude as concentrations in the river.

1/ Anadromous Fisheries Branch Administrative Report No. 75-3

Ufrint CDWA Ex 2

INTRODUCTION

California's major striped bass population inhabits the estuary of the Sacramento-San Joaquin River system and adjacent coastal areas (Chadwick, 1967). Primary spawning areas are the Sacramento River from its confluence with the American River upstream to Colusa and the San Joaquin River from Antioch to Venice Island. The main nursery area for young-of-the-year striped bass is from the Sacramento-San Joaquin Delta downstream to upper San Pablo Bay.

Turner and Chadwick (1972) demonstrated that survival of young-of-the-year striped bass in the estuary is highly correlated with mean river outflow in June-July. Highest survival occurs in years with highest outflows.

Two of the most plausible explanations for this relationship are: (1) that estuarine productivity is increased by high outflows, or (2) that losses of eggs and young through the water diversions reduce the bass population more when flows are low than when they are high.

The largest diversions are the Federal Central Valley Project and the State Water Project pumping plants in the south Delta. Water exports by these facilities averaged 31% of the total June-July Delta inflows for the years 1959-1973.

The second most important source of water removal is through the numerous, small agricultural diversions in the Delta. These sources diverted an average of about 27% of the June-July inflow from 1959 to 1973 (California Department of Water Resources, unpublished data).

My study was initiated to evaluate losses of striped bass eggs and young through these diversions by comparing catches of eggs and young in the diversions with catches in the adjacent river channel.

Irrigators in the Delta generally siphon water from the channel, apply it to the fields through a series of ditches, then pump the remainder back into the channel. The siphons are permanent structures, and most are from 15.2 to 30.4 cm (6-12 inches) internal diameter. The siphons are unscreened. Intakes are usually set to draw water from two to three feet above the river bottom, however, their exact position may vary somewhat due to siltation or other causes. Exact quantities of water diverted by individual siphons are unknown since none are metered.

SAMPLING PROCEDURES

Samples were collected from seven diversions on Sherman Island and four stations in the San Joaquin River adjacent to Sherman Island (Figure 1). The river was surveyed on alternate days from April 30 to July 13. Siphons in use were sampled on 10 weekdays when the river was not surveyed in May, on 2 days in June, and on 3 days in July (Table 1).

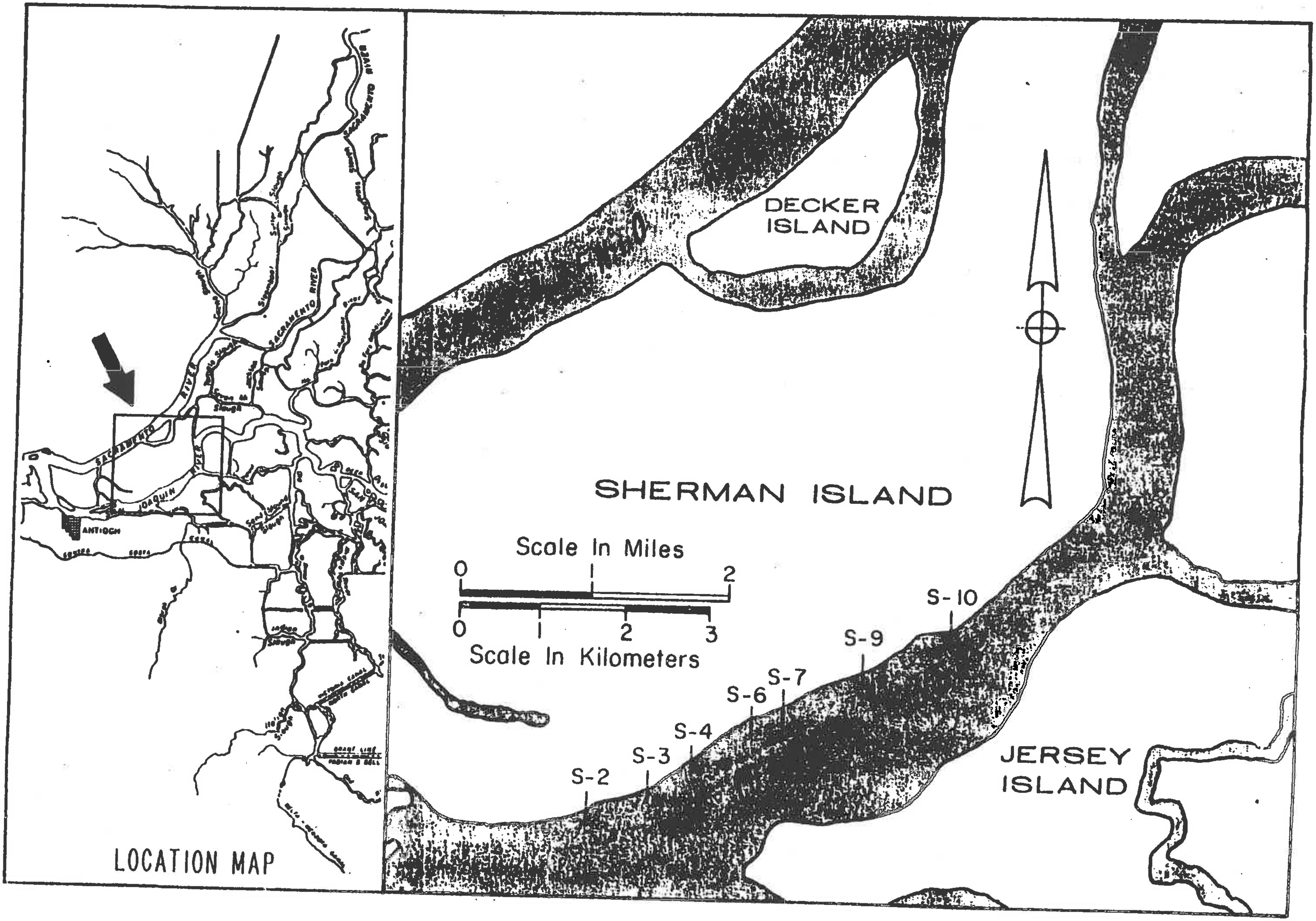
DECKER ISLAND
SHERMAN ISLAND
JERSEY ISLAND
Scale In Miles
0 1 2
0 1 2 3
Scale In Kilometers
S-2
S-3
S-4
S-6
S-7
S-9
S-10
SACRAMENTO RIVER
SAN JOAQUIN
ANTIOCH
LOCATION MAP

TABLE 1

Total Catches of Striped Bass Eggs and Young
From Agricultural Diversions on Sherman Island

Total Catch Striped Bass Young
Siphon

Date	S-2	S-3	S-4	S-6	S-7	S-9	S-10	Total
5-3							3	3
5-5							3	3
5-9						3	0	3
5-11						9	4	13
5-15						0		0
5-17						1		1
5-19		8				0		8
5-23		11	1			0		12
5-25		59	3					62
5-31		64	20		39			123
6-2		43	2		19			64
6-14							22	22
7-7		2		2				4
7-11		4						4
7-14	2							2
Total	2	191	26	2	58	13	32	324

Total Catch Striped Bass Eggs
Siphon

Date	S-2	S-3	S-4	S-6	S-7	S-9	S-10	Total
5-3							0	0
5-5							0	0
5-9						0	0	0
5-11						49	0	49
5-15						131		131
5-17						7		7
5-19		35				5		40
5-23		2	1			0		3
5-25		74	15					89
5-31		4	3		1			8
6-2		0	1		1			2
6-14							0	0
7-7		0		0				0
7-11		0						0
7-14	0							0
Total	0	115	20	0	2	192	0	329

The siphons were sampled with a small mesh net set on the bottom of the irrigation ditch close to the siphon discharge for 10 minutes. The net mouth rested about 5 cm (2 inches) off the bottom. Variations in ditch width and depth precluded complete sampling of the water flow. Usually 60 to 80% of the siphon discharge was sampled by the net.

In the river, a small mesh net was towed from a boat for 10 minutes. Engine speed was varied to maintain the angle of the towing cable at 72±2 degrees. All tows were diagonal from bottom to surface so all depths were sampled equally.

Samples were preserved in 10% formalin at the time of collection. In the laboratory fish eggs and young were sorted, identified, and counted. Striped bass young were measured to the nearest mm Standard Length (SL).

SAMPLING GEAR

The diversions were sampled with a net constructed of 7.87 mesh per cm (20 mesh per inch) Marquisette nylon netting, having an opening of approximately 930 microns[2/]. The net was 1.83 m (6 ft) in length and tapered from a square mouth 30 cm (11.8 inches) per side to a collecting bucket with a mouth 6.7 mm (2.6 inches) in diameter. The

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2/ #73-503 Marquisette, Nylon Netting, Turtox Inc. Chicago, Illinois.

collecting bucket was a polyethylene jar with a 7 X 8 cm (2.7 X 3.1 inch) opening on the side covered with 11.8 mesh per cm (30 mesh per inch) stainless steel bolting cloth. Water flow through the net was measured by a Pygmy-type flow meter3/ mounted in the net mouth.

The river was also sampled with a net constructed of 7.87 mesh per cm Marquisette. It was 3.35 m (11 ft) long and tapered from a mouth .45 m^2 (4.9 ft^2) to a collecting jar identical to that described above. Water flows were metered and the net was mounted on a ski frame.

RESULTS

A total of 329 bass eggs and 324 bass young were caught in the diversions (Table 1).

Daily catches of eggs in the diversions varied from 0 to 18.3/m^3. The mean daily catch was 2.0 eggs/m^3. Daily egg catches in the river varied from 0 to 5.8/m^3. The mean catch was 1.0 egg/m^3 (Table 2).

Young bass catches were less variable than the egg catches. The daily catch of young in the diversions ranged from 0 to 2.0/m^3. The mean was 0.5 young/m^3. These fish ranged from 4 to 16 mm SL. Their mean length was 7.5 mm. The mean catch of young bass in the river was 0.8/m^3 and the daily catch varied from 0.5 to 2.2 young/m^3. The mean length of young bass from the river was smaller (7.0 mm)

3/ #005-WA-130 flow meter, Kahl Scientific Instrument Company, El Cajon California.

1972

TABLE 2

Catches/m³ of Striped Bass Eggs and Young from Agricultural Diversions and San Joaquin River

Date[a]	Striped Bass Eggs/m³		Striped Bass Young/m³		Mean Length	
	Ag. Div.	S.J. River[b]	Ag. Div.	S.J. River[b]	Ag. Div.	S.J. River[b]
5-3	0	.10	.06	.11	5.7	5.5
5-5	0	.04	.05	.08	6.7	6.0
5-9	0	.03	.17	.35	6.0	5.9
5-11	7.23	4.37	1.96	.34	6.8	5.8
5-15	18.35	.99	0	.66	—	5.8
5-17	1.31	.76	.19	.80	5.0	5.9
5-19	.91	5.79	.18	1.39	7.4	5.9
5-23	.04	.19	.10	2.22	7.4	6.2
5-25	1.87	.07	1.30	2.23	7.3	6.6
5-31	.08	.71	1.21	1.42	8.0	7.1
6-2	.02	.32	.77	1.25	8.2	7.3
6-14	0	.10	.56	.63	11.5	8.2
7-7	0	0	1.12	.11	8.5	10.7
7-11	0	0	.05	.05	9.8	10.0
7-14	0	—	.04	—	7.0	—
Mean	2.00	1.00	.52	.80	7.5	7.0
Standard Deviation	4.73	1.73	.59	.73	1.6	1.6
Variance	22.38	2.99	.35	.53	2.6	2.6

a Date of agricultural diversion sampling.

b San Joaquin River values are the mean of the mean catch at the four river sampling stations from the day proceeding and following the date of diversion sampling.

but their size range (3-34 mm) was larger than for the bass collected in the diversions (Table 2).

Nineteen other young fish were also taken in the diversions. Thirteen of these were smelt, three were shad, and three were catfish.

ANALYSIS AND DISCUSSION

Due to large catch variations and zero catches, catches plus 1 were transformed to logarithms for analysis.

Differences in the daily catch of eggs/m^3 from the two sources did not vary significantly from zero ($t = .557$, d.f. = 13). Similarly, differences in the daily catch of bass/m^3 did not vary significantly from zero ($t = 1.259$, d.f. = 13).

There was no statistically significant difference between the daily mean lengths of bass caught in the river and those diverted ($t = 1.53$, d.f. = 12); however, bass between 16 and 34 mm were taken only in the river. Two possible explanations for this finding are: (1) that large bass swim well enough to avoid the influence of running siphons, and (2) the large bass avoided the small mouth of the diversion net. The first of these explanations is the most plausible.

Young bass about 3 mm long were taken in the river, but not in the diversions. These fish probably represent late term eggs ruptured by abrasion caused by the relatively high water velocities through the towed net.

Subsequent studies have shown that the material used for both sampling nets is inefficient at catching young bass shorter than 8 mm (Miller, MS.). This deficiency biased estimates of bass densities and mean lengths; however, both sets of data should be biased equally so comparisons of the respective catches are probably valid.

Bias was introduced by comparing diversion catches, which were drawn from a fixed level in the water column, to catches made by a diagonal tow in the water. Striped bass eggs tend to be most concentrated near the bottom of the water column (Turner, MS.). The siphon intakes are also near the bottom so this probably explains why the catch of eggs/m^3 in the diversions was greater than the catch in the river. Vertical stratification may also have affected the catch of young bass.

Although the bias caused by vertical stratification of eggs and young precludes definitive comparisons between diversion and river catches, the catches were of the same general magnitude; hence, I conclude that diverted concentrations of bass eggs and young up to 16 mm long approximate concentrations in the river.

ACKNOWLEDGEMENTS

This program was supervised by Jerry Turner. Thanks are due the many seasonal aids who performed most of the lab and field work. Donald Wyatt constructed sampling equipment and aided with the field work. I thank Lee Miller and Donald Stevens for critically reviewing this report.

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Tom Zuckerman

U. S. FISH AND WILDLIF
SERVICE

EXHIBIT #3

1978 Hearing exhibit.

Irrigation Diversion Study Summary

There are numerous water diversions along the Sacramento River and its tributary streams. Very few of these diversions are screened to prevent fish losses.

In view of the National interest in anadromous fish and the significant State and Federal investments in hatcheries and production of chinook salmon and steelhead, the California Department of Fish and Game assisted by the U.S. Fish and Wildlife Service conducted a pilot survey to evaluate the impact of water diversion structures on migrating juvenile salmonids.

Fyke nets with live boxes were used to sample the discharge. Initially, fyke nets with stretched mesh sizes varying from 1½ inch to 1 inch to ½ inch were used. To increase netting efficiency we switched to fyke nets of ½ inch stretched mesh. An inner fyke of ¼ inch stretch mesh was attached near the opening. Additionally, an experimental ¼ inch stretch mesh funnel net with inner fyke is being used.

Fyke nets were set as close to the discharge outlet as possible. The funnel net slid over a discharge pipe.

Nets were checked every 24 hours. All fish captured were recorded, measured and released. To identify previously captured fish, the upper lobe of the caudal fin was clipped.

To test net efficiency, chinook salmon fingerlings were marked and released, either into the pipe before it discharges into the ditch or directly in front of the discharge.

The selection of sampling locations was based primarily on the site's capacity to accommodate the net. Six sites were selected for use; four on Ryer Island and one each on Grand and Sherman Islands.

Ryer Island

1. water source: Steamboat Slough
   intake structure: siphon
   intake diameter: 20 inches
   diversion location: right side of Steamboat Slough approximately 0.9 mile upstream of Howard Landing Ferry
   average discharge flow: 10 cfs

WRINT CDWA Ex 3

2. water source: Miner Slough
   intake structure: siphon
   intake diameter: 30 inches
   diversion location: left side of Miner Slough approximately 0.2 mile upstream of State Highway 84 bridge
   average instantaneous flow: 19 cfs

3. water source: Miner Slough
   intake structure: siphon
   intake diameter: 18 inches
   diversion location: left side of Miner Slough approximately 0.5 mile upstream of the Elevator Road-Ryer Island West Road intersection
   average discharge flow: 4 cfs

4. water source: Cache Slough-Deepwater Ship Channel
   intake structure: siphon
   intake diameter: 14 inches
   diversion location: left side of Cache Slough-Deepwater Ship Channel approximately 3.1 miles downstream of the State 220-Ryer Island West Road intersection
   average discharge flow: 6 cfs

Grand Island

water source: Steamboat Slough
intake structures: (2) siphons and (1) pump
intake diameters: 18 inches and 14 inches respectively
diversion location: left side of Steamboat Slough approximately 0.3 mile downstream of the Howard Landing-Grand Island Road intersection
average instantaneous flow: 14 cfs

Sherman Island

water source: Sacramento River
intake structure: siphon
intake diameter: 20 inches
diversion location: left side of Sacramento River approximately 1.7 miles downstream of the Three Mile Slough bridge crossing
average discharge flow: 10 cfs

26 species of fish were captured. In addition, we captured large numbers of opossum shrimp, and crayfish, several muskrats, a bullfrog, pond turtle, and western fence lizard.

Fish species and numbers taken per site are listed below.

SPECIES		NUMBERS/SITE					
Common Name	Scientific Name	Ryer Island				Grand Is.	Sherma Is
		1	2	3	4		
Pacific lamprey	_Entosphenus tridentatus_	2	-	10	4	3	4
river lamprey	_Lampetra ayressii_	3	2	-	1	1	-
American shad	_Alosa sapidissima_	-	-	1	4	-	2
threadfin shad	_Dorsoma petenense_	-	-	3	-	-	7
longfin smelt	_Spirinchus thaleichthys_	8	68	17	4	-	183
chinook salmon	_Oncorhynchus tshawytscha_	164	14	32	16	-	4
steelhead trout	_Salmo gairdnerii gairdnerii_	1	-	1	-	-	-
carp	_Cyprinius carpio_	21	-	6	-	-	-
goldfish	_Carassius auratus_	5	3	11	-	-	-
Sacramento blackfish	_Orthodon microlepidotus_	-	6 1/	-	-	-	-
Sacramento hitch	_Lavinia exilicauda_	8	16 2/	4	-	93	-
Sacramento squawfish	_Ptychocheilus grandis_	17	23	5	-	1	-
white catfish	_Ictalurus catus_	143	225	271	66	24	96
channel catfish	_Ictalurus punctatus_	-	-	1	-	-	-
yellow bullhead	_Ictalurus natalis_	-	-	-	2	-	-
mosquito fish	_Gambusia affinis_	-	-	2	-	-	-
starry flounder	_Platichthys stellata_	-	-	-	-	-	1
striped bass	_Morone saxatilis_	1	1	2	-	-	-

SPECIES		NUMBERS/SITE					
Common Name	Scientific Name	Ryer Island				Grand Is.	(Sher Sn
		1	2	3	4		
largemouth bass	_Micropterus salmoides_	1	-	-	-	-	
smallmouth bass	_Micropterus dolomieui_	-	1 3/	-	-	-	
green sunfish	_Lepomis cyanellus_	23	20 4/	16	-	3	
bluegill	_Lepomis macrochirus_	-	1 5/	-	-	-	
black crappie	_Pomoxis nigromaculatus_	2	-	-	1	-	
log perch	_Percinia caprodes_	2	4 6/	3	-	-	
tule perch	_Hysterocarpus traskii_	43	13	40	21	4	
Pacific staghorn sculpin	_Leptocottus armatus_	-	3	1	3	1	
crayfish	_Astacidae_	-		-		-	
opossum shrimp	_Neomysis spp._						
pond turtle	_Clemmys marmorata_	-	-	1	-	-	
bullfrog	_Rana catesbeiana_	-	1	-	-	-	
western fence lizard	_Sceloporus occidentalis_	1	-	-	-	-	
muskrat	_Ondatra zibethica_	-	-	-	-	-	1

1/ 2 taken with electro-shocker

2/ 9 " " "

3/ 1 " " "

4/ 7 " " "

5/ 1 " " "

6/ 2 " " "

DELTA UNSCREENED
IRRIGATION DIVERSIONS

There are an estimated 400 irrigation diversions in the Sacramento-San Joaquin Delta. This estimate reflects data compiled from DWR Bulletin 130-64, Volume II, N.E. California; May, 1966 which lists the number of diversions, at that time, for the San Joaquin River between Vernalis and Stockton; the Old River between the confluence of Tom Paine Slough and The Contra Costa Canal; and the Sacramento River between the Tower Bridge and Rio Vista as well as our best estimate of the number of diversions in the Delta.

Ryer Elevator

King Salmon

Numbers	Date	Size (mm)
0	4-8-76	-
0	4-12-76	-
3	4-13-76	52,42,62
2	4-14-76	67,69
1	4-15-76	72
2	4-16-17-18-76 1/	66,84
1	4-19-76	103
1	4-20-76	93
0	4-21-76	-
1	4-22-76	88
3 2/	4-26-76	90,81,88
37 2/	4-27-76	87,78,79,80,86,78,81, 77,92,90,84,83,82,75, 78,74,88,84,81,79,76, 87,80,86,80,75,82,70, 74,85,96,75,80,83,88, 76,80.
1	4-27-76	79
0	4-28-76	-
2	3/ 4-29-76	85,82
18 2/	4-29-76	80,92,65,76,78,83,64, 76,77,70,70,71,77,79, 77,86,90

1/ Left net in over weekend.
2/ Taken with a 1/8" bobbinet beach seine.
3/ Began to use 1/4" mesh fyke nets.

Ryer Elevator (continued)

Numbers	Date	Size (mm)
7 1/	4-30-76	Not measured
21	5-3-76	77,78,82,77,72,75,80, 68,78,90,75,78,79,70, 79,77,75,74,70,75,75
2	5-4-76	90,84
6 1/	5-4-76	78,72,76,82,84,75,
1	5-5-76	82
2 1/	5-5-76	78,83
1	5-6-76	89
2	5-10-76	94,71
4 1/	5-10-76	86,84,100,80
0	5-11-76	-
3	5-12-76	85,87,81
1	5-13-76	82
4 1/	5-13-76	82,96,84,77
3	5-17-76 2/	88,87,78
5 1/	5-17-76	82,98,91,84,77
0	5-18-76	-
0	5-19-76	-
0	5-20-76	-
1	5-21-76	98
0	5-22-76	-
1 1/	5-23-76	98

1/ Taken with a 1/8" bobbinet beach seine.
2/ Began to use 1/8" funnel net.

Ryer Elevator (continued)

Numbers	Date	Size (mm)
0	5-24-76	-
0	5-25-76	-
4 1/	5-26-76	57,92,94
0	5-27-76	-
0	5-28-76	-
0	5-29-76	-
1	5-30-76	62
0	5-31-76	-
0	6-1-76	-
0	6-2-76	-
1 2/	6-3-76	75
0	6-4-76	-
0	6-5-76	-
0	6-6-76	-
0	6-7-76 3/	-
1	6-8-76	95
0	6-9-76 3/	-
0	6-10-76 3/	-
0	6-14-76	-
0	6-15-76	-

2/ Taken with 1/8" bobbinet beach seine.
1/ Includes partly digested remains of one king salmon.
3/ Ran efficiency test ~~100% recapture.~~

Ryer Elevator (continued)

Type of Trap & Number of Fish Taken		Dates Used	Number of hours [1/]
(1) Variable mesh trap	12	4-8-76 to 4-28-76	345 [2/]
(2) 1/4 inch mesh w/inner fyke	33	4-29-76 to 5-16-76	230 [2/]
(3) 1/8 inch bobbinet funnel w/inner fyke	10	5-17-76 to 6-15-76	621 [2/]
Total Fish Taken in Trap	55	Total Hours	1,196

Efficiency

	Number Planted	Number Recaptured	%
Variable mesh fyke	50	11	22
1/4" mesh fyke w/inner fyke	56	14	25
1/8" mesh funnel w/inner fyke	50	50	100

Take/hours/trap

Variable mesh 0.03

1/4 inch mesh fyke 0.14

1/8 inch mesh funnel 0.02

Total fish taken w/seine 88

Total hours seined 10

Take/hour 8.8

1/ 23 hours/day.

2/ includes hours efficiency test was run

Ryer North

King Salmon

Numbers	Date	Size (mm)
0	4-1-76	-
0	4-12-76	-
0	4-13-76	-
1	4-14-76	52
0	4-15-76	-
2	5-10-76 1/	75,85
4	5-11-76	77,87,101,86
0	5-12-76	-
1	5-13-76	85
0	5-17-76	-
0	5-18-76	-
1	5-19-76	105
1	5-20-76	94
0	5-21-76	-
0	5-22-76	-
1	5-23-76	68
0	5-24-76	-
1	5-25-76	98
0	5-26-76	-
0	5-27-76	-
0	5-28-76	-

1/ Began to use 1/4 inch mesh.

Ryer North (continued)

Numbers	Date	Size (mm)
1	5-29-76	98
0	5-30-76	-
1	5-31-76	62
0	6-10-76 1/	-
0	6-11-76 1/	-
0	6-14-76	-

Type of trap and number of fish taken		Dates Used	Number of hours 2/
Variable mesh	1	4-1-76 to 4-15-76	138 3/
1/4 inch mesh	13	5-10-76 to 6-14-76	483 3/
Total fish	14	Total hours	621

Efficiency

	Number Planted	Number Recaptured	%
Variable mesh	77	46	60
1/4 inch mesh	75	64	85

Fish take/trap/hour

Variable mesh	0.01
1/4 inch mesh	0.03

Volume of water sampled 975 acre feet

1/ Conducted efficiency test.
2/ 23 hours/day.
3/ Includes hours efficiency test was run.

Ryer Superintendent

King Salmon

Numbers	Date	Size (mm)
0	4-8-76	-
0	4-12-76	-
0	4-13-76	-
0	4-14-76	-
0	4-15-76	-
0	5-17-76 1/	-
8	5-18-76	84,73,75,59,78,74, 66,81
1	5-19-76	65
1	5-20-76	82
0	5-21-76	-
0	5-22-76	-
1	5-23-76	72
2	5-23-76 2/	102,83
1	5-24-76	60
1	5-25-76	71
1	5-26-76	61
0	5-27-76	-
0	5-28-76	-
0	5-29-76	-
0	5-30-76	-

1/ Utilizing 1/4 inch mesh nets.
2/ Seined delivery channel.

Ryer Superintendent (continued

Numbers	Date	Size (mm)
0	5-31-76	-
0	6-1-76	-
0	6-2-76	-
0	6-3-76	-
0	6-4-76	-
0	6-5-76	-
0	6-6-76	-
0	6-7-76	-
0	6-8-76	-
1	6-9-76	78
0	6-10-76 1/	-
0	6-11-76 1/	-

1/ Efficiency tests.

Ryer Superintendent (continued

Type of trap and number of fish taken		Dates Used	Number of hours [1]
Variable mesh	0	4-8-76 to 4-15-76	138 [2]
1/4 inch mesh	15	5-17-76 to 6-11-76	575 [2]
Total fish	15	Total hours	713

Efficiency

	Number Planted	Number Recaptured	%
Variable mesh	60	16	27
1/4 inch mesh w/inner fyke	58	10	17

Take/hour/trap

Variable mesh	0
1/4 inch mesh	0.03

Volume of water sampled 354 acre feet

Total fish taken w/seine 2

Total hours seined 0.5

Take/hour 4

1/ 23 hours /day.
2/ Includes hours efficiency test was run.

Numbers	Date	Size (mm)
0	5-21-76	-
1	5-22-76	102
0	5-23-76	-
4	5-24-76	65,86,102,86
2	5-25-76	71,94
0	5-26-76	-
3	5-27-76	73,95,92
0	5-28-76	-
0	5-29-76	-
1	5-30-76	65
0	5-31-76	-
1	6-1-76	93
0	6-2-76	-
0	6-3-76	-
1	6-4-76	68
0	6-5-76	-
0	6-6-76	-
0	6-7-76	-
0	6-8-76 1/	-
0	6-9-76	-
0	6-10-76	-
0	6-11-76 1/	-
0	6-14-76 1/	-
0	6-15-76 1/	-

1/ Efficiency tests conducted.

Ryer BM-9

King Salmon

Numbers	Date	Size (mm)
0	4-1-76	-
2 1/	4-19-76	78
0	4-20-76	-
1	4-21-76	82
1	4-22-76	79
0	4-26-76	-
0	4-27-76	-
0	4-28-76	-
0	4-29-76 2/	-
6	5-3-76	76,80,72,85,72,86
2	5-4-76	86,76
1	5-5-76	82
1	5-6-76	76
1	5-10-76	91
0	5-11-76	-
1	5-12-76	83
0	5-13-76	-
2	5-17-76	90,88
0	5-18-76	-
1	5-19-76	88
1	5-20-76	91

1/ Partly digested.
2/ Began to use 1/4 inch mesh fyke net.

Type of trap and number of fish taken		Dates Used	Number of hours 1/
Variable mesh	4	4-8-76 to 4-28-76	184 2/
1/4 inch w/inner fyke	29	4-29-76 to 6-15-76	828 2/
Total fish	33	Total hours	1,012

Efficiency

	Number Planted	Number Recaptured	%
Variable mesh	58	38	66
	53	45	85
1/4 inch w/inner fyke	94	27	29
	50	25	50

Fish take/hour/trap

Variable mesh 0.02

1/4 inch mesh 0.03

Volume of water sampled 334 ac. ft.

1/ Fished 23 hours/day.

2/ Includes hours efficiency test was run

Shelley Rch.

King Salmon

Numbers	Date	Size (mm)
0	4-1-76	-
0	4-8-76	-
0	4-16-17-18-76 1/	-
0	4-19 to 4-22-76	-
0	4-26 to 4-29-76 2/	-
0	5-3 to 5-6-76	-
0	6-1 to 6-8-76 3/	-

Fish taken 0 Hours fished 575 4/

Efficiency

	Numbers Planted	Numbers Recaptured	%
Variable mesh	76	6	8
1/4 inch mesh	50	29	58

Volume of water sampled 665 acre feet.

1/ Left net in over weekend.
2/ Began to use 1/4 inch mesh.
3/ Efficiency tests ran 6-7 and 6-8.
4/ 23 hours/day.

Sherman Is.

King Salmon

Numbers	Date	Size (mm)
0	4-8-76	-
0	4-12-76	-
0	4-13-76	-
1	4-14-76	71
0	4-15-76	-
0	4-19-76	-
1	4-20-76	95
0	4-21-76	-
0	4-22-76	-
0	4-26-76	-
0	4-27-76	-
0	4-28-76	-
0	4-29-76 1/	-
0	5-3-76	-
1	5-4-76	73
0	5-5-76	-
0	5-6-76	-
1	5-10-76	92
0	6-14-76 2/	-
0	6-15-76 2/	-

1/ Began to use 1/4 inch mesh.
2/ Efficiency tests run for 8 hours.

Sherman Is. (continued)

Type of trap and number of fish taken		Dates Used	Number of hours
Variable mesh	2	4-8-76 to 4-28-76	284 1/
1/4 inch mesh	2	4-29-76 to 5-10-76	146 1/
Total fish	4	Total hours	430

Efficiency

	Number Planted	Number Recaptured	%
Variable mesh	50	19	38
1/4 inch mesh	50	26	52

Fish take/hour/trap

Variable mesh 0.007

1/4 inch mesh 0.01

Volume of water sampled 355 acre feet.

1/ Includes 8 hours efficiency tests were run.

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DRAFT DBO
4/3/81

SCREENING EXISTING AGRICULTURAL DIVERSIONS IN THE SACRAMENTO-SAN JOAQUIN ESTUARY AND ITS TRIBUTARIES, A REVIEW OF THE PROBLEM

by

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SUMMARY

Approximately 4,300 diversions in the Sacramento-San Joaquin Delta and its tributaries exist, most of which are unscreened. These diversions are causing the loss of at least 13 million chinook salmon and numerous other fish annually. The impacts of the loss of 13 million juvenile chinook salmon can be placed in perspective by computing the numbers which are lost from the fishery as a result of these diversions. The resulting estimate would be 65,000 fish lost from the ocean fishery and an additional 32,500 fish which fail to return to the spawning grounds.

The Department of Fish and Game has the authority, under existing law, to screen all of these diversions but the owners would not be responsible for paying any of the costs, installation, operation, or maintenance in most instances. Therefore, all costs of screening, operating, and maintaining these diversions would have to be accomplished with public funds. We estimate the cost of screening these diversions at approximately 23.5 million dollars.

The following recommendations should be instituted to assist in solving these problems:

1. We should continue to require that all new diversions affecting salmon and steelhead be screened under Section 6100 of the Fish and Game Code.

2. We should seek new legislation to extend the provisions of Section 6100 of the Fish and Game Code to all new diversions which, in the opinion of the Department, will impact fish resources.

3. We should continue to screen existing diversions with DFG funds as surplus funds become available.

4. We should seek funds from the General Fund or the Energy and Resources Fund to cover the costs of this program.

5. We should seek legislation to shift the Operation and Maintenance costs of all existing diversions to the water user.

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INTRODUCTION

The purpose of this report is to provide an estimate of the number of unscreened diversions in the Sacramento-San Joaquin Estuary and its tributaties, and to assess the impact of these unscreened diversions on the fishery resources of the system. The report will also propose some solutions to the problem.

Formal studies on the effects of unscreened water diversions in California date back to at least 1931, when an investigation of fish losses at the Glenn-Colusa Irrigation District's intake was conducted. Since that time a number of studies, including several recent studies in the Delta, have been conducted. This evaluation is based on the results of these studies. The estimates suffer from small sample sizes, wide variability in the results, and the irregular nature of the sampling. Obviously, a comprehensive sampling program would yield better results. In spite of these shortcomings, the results appear to be reasonable and are conservative estimates of the problem.

FISH SCREEN LEGISLATION

The Fish and Game Code has three articles which set forth requirements for fish screens on water diversions in California. The first two (Division 6, Chapter 3, Articles 3 and 4) are applicable to all diversions constructed prior to 1971 and to diversions constructed since 1971 which do not affect salmon and steelhead populations. The third (Division 6, Chapter 3, Article 5) is applicable to diversions constructed since 1971 which affect salmon and steelhead populations.

Diversions which, in the opinion of the Department of Fish and Game, will affect salmon and steelhead populations and are constructed after 1971, must have screens constructed, operated, and maintained by the owner. Screens on diversions built prior to 1971, and newer diversions which do not affect salmon and steelhead, require funds from the Fish and Game Preservation Fund. If the diversion is larger than 250 cfs, the costs of installation, operation, and maintenance are shared, while the Fish and Game Preservation Fund bears the full cost of installing, operating, and maintaining screens for diversions of less than 250 cfs. Thus, most of the diversions identified in this study would have to be screened by the Department, using funds from the Fish and Game Preservation Fund.

RESULTS

Number of Diversions

Estimates of the number of diversions were obtained from two sources. The first, DWR Bulletin #130 (series for various years), allows an accurate inventory of the number of sites and pumps and size of pumps for the areas covered (Table 1)

TABLE 1

Summary of Diversions from DWR Bulletin 130 Series

	Sites	Pumps	Size Range in Inches
Sacramento System			
Sacramento River	688	945	1¼" - 50"
Feather River	78	101	3" - 46"
Yuba River	17	22	4" - 24"
American River	17	32	4" - 36"
Sub Total	800	1,100	
San Joaquin System			
San Joaquin River	492	602	2" - 36"
Merced River	39	44	4" - 20"
Stanislaus River	24	31	8" - 20"
Tuolumne River	23	28	3" - 21"
Mokelumne River	116	125	1½" - 18"
Sub Total	694	830	
TOTAL	1,494	1,930	

Unfortunately, these records do not include the bulk of the interior Delta diversions. The second source of information is the list of property owners within the legal Delta. This list, prepared for the dry year hearings by the State Water Resources Control Board, shows 2,842 individual property owners. Assuming a minimum of one diversion per property owner, we have 2,842 diversions within the legal Delta to contend with. It is highly probable that this number if higher, since many owners have more than one parcel and many parcels have more than one diversion point.

Combining the results of the two inventories and eliminating duplication, we get a figure of 4,336 diversion sites. These diversions range in size from 1½" to 50". The larger diversions such as the Glenn-Colusa Irrigation District facility near Hamilton City on the Sacramento River have in some cases already been screened. Larger unscreened diversions include the Contra Costa Canal intake in the Delta, Sunset Pumps on the Feather River, and the Tisdale Diversion on the Sacramento River.

Estimates of internal Delta water diversions vary, by time of the year and by water year. However, during the months in question (A, M, J, J, A) the gross volume of water diverted is comparable to the Federal pumping plant in the south Delta, on the order of 4,000 cfs.

Estimates of the diversions upstream of the Delta were developed from the Central Valley Consumptive Use of Applied Water figures provided by the Department of Water Resources. These figures underestimate the magnitude of the diversions because they are net losses and account for tailwater returning to the river.

Diversions on the Sacramento River and its tributaries above the Delta range in size from one to 306,000 acre-feet annually. The maximum monthly diversion capacity is approximately 19,000 cubic feet per second of which approximately 12,000 cfs remains to be screened. On the San Joaquin River side, the diversions range in size from one to 190,000 acre-feet annually with a maximum monthly diversion capacity of approximately 13,000 cfs, of which approximately 7,500 cfs remains unscreened. Combining all the estimates, we arrive at a grand total of approximately 23,500 cfs of unscreened diversions in the system.

Chinook Salmon Impacts

Chinook salmon are present in the system on a year-round basis today, however, the bulk of the population migrates past the diversions between February and June of each year. Thus, many of the agricultural diversions would only impact a portion of the run. This is in marked contrast to the CVP-SWP and other municipal and industrial diversions which operate continuously throughout the year.

Several studies are available which allow us to estimate the impact of unscreened diversions on juvenile chinook salmon. As a result, many of the larger, older diversions have been screened by the Department and all new diversions (since 1972), which in the opinion of the Department would affect salmon or steelhead, have been required to screen their intakes.

The most recent surveys of unscreened diversions in the Delta were conducted in 1976 by the U. S. Fish and Wildlife Service and the Department of Fish and Game (Table 2). Comparing these data to similar figures collected at the State and Federal Fish Protective facilities shows that the unscreened diversions studied had significantly higher losses per unit of water diverted than did the larger State and Federal facilities. Since the salvage of chinook salmon at the Federal facility during the spring of 1976 was approximately 100,000 fish, one estimate of the losses to the unscreened Delta diversions during the spring of 1976 would be 1,500,000 chinook salmon, the ratio of salmon catches times the salvage of fish at one of the facilities ($1.38 \div 0.09 = 15.3 \times 100{,}000 \cong 1{,}500{,}000$). Since 1976 was a low flow year and a year of low chinook salmon numbers in the Delta, this estimate is likely to be conservative. Salmon salvage totals at the Federal facility for wetter years such as 1974 have been as high as 250,000 fish, a figure which would produce a loss estimate for Delta diversions of 3,825,000 fish.

Similar studies at the Sunset Pumps on the Feather River (Table 2), conducted during 1977 and 1978, showed higher loss figures for unscreened diversions along the upper river (Menchen, MS). The total loss for the unscreened diversions on the Sacramento River could reach 10.4 million fish ($4.66 \div 0.09 = 51.8 \times 100{,}000 \times 2 \cong 10{,}400{,}000$). We doubled the total because the upper river diversions are approximately twice as much in total as those of the pumping plant. Again, this estimate could be larger if it were expanded by the catches at the facilities in a wetter year. All of these recent studies are similar to those presented by Hallock and Van Woert in 1979, as well as the results of other evaluations conducted by the Fish Facilities Program of the Interagency Ecological Study Program.

Combining these estimates, we get a number of approximately 13 million juvenile chinook salmon lost to these diversions. The impact of this loss can be placed in perspective by computing the numbers which would be lost from the fishery as a result of these diversions.

If we assume that the return rates for marked hatchery smolts released upriver are a conservative estimate for the survival of these fish, we can generate estimates of the returns we would expect from a screening program.

Our experience has been that marked hatchery smolts released upriver return to the fishery at a 0.5% rate (Jack Robinson, pers. comm.), with half again as many showing up in the escapement. Applied to the 13 million loss estimate, we get approximately 65,000 fish ($13 \times 10^6 \times 0.005 = 65{,}000$) in the catch and 32,500 fish in the spawning escapement.

STRIPED BASS IMPACTS

Several studies are also available which allow us to estimate the impact of unscreened diversions on juvenile striped bass. Both Heubach (MS) and Allen (1975) directly sampled diversions in the Delta to establish losses. A third estimate of losses can be obtained by adjusting the salvage totals from the State's Fish Protective Facility by the efficiencies established during the evaluation of the facility (Skinner, MS), to produce an estimate of the number of fish entrained to the facilities.

TABLE 2

Summary of Chinook Salmon Evaluations

DELTA

	Salmon/AF	
USFWS and DFG (A M J - 1976)		
Ryer North	1.25	
Ryer Superintendent	4.09 - 0.05	
Sherman Island	0.19	
Shelley Ranch	0.00	
$\bar{x}$		1.38
State and Federal Fish Facilities (A M J - 1976)		
State	0.15	
Federal	0.03	
$\bar{x}$		0.09

FEATHER RIVER

Sunset Pumps (1972, 1977-1978)		
1972	5.81	
1977	6.15	
1978	2.03	
$\bar{x}$		4.66

Comparing Heubach's (MS) results for the Contra Costa Canal intake and Allen's (1975) results for unscreened diversions on Sherman Island with the data from the State's Fish Protective Facility establishes that the smaller unscreened diversions in the Delta have similar losses per unit of water diverted as do the larger facilities (Table 3).

To put this in perspective, during 1974 the Federal Pumping Plant salvaged over eight million juvenile striped bass during the period from May to August. Thus, the unscreened Delta diversions could be resulting in a loss of striped bass of at least of this magnitude.

We can also relate the impact of these unscreened diversions to the Striped Bass Index, using statistical relationships between the Index, water flow, and water diversions. This results in an estimate that screening or relocating these diversions would result in an increase of about 15 index units. We should keep in mind that we are extrapolating beyond our data points in making these estimates. The Striped Bass Index has ranged between 8.7 and 118.4 during the period between 1959 and 1979 and our goal has been an index of 106. Thus, this approach indicates screening Delta diversions might increase the Striped Bass Index by more than 10%.

Impacts on Other Species

Throughout the sampling which was conducted to identify the losses of chinook salmon and striped bass, other species were taken. These species include almost all of the fish identified from the Delta. Since a number of these organisms are the food source of the larger fish in the Delta and many also provide recreation and food for people, these losses are significant. Quantifying these losses has not been attempted and it is only mentioned to point out that these unscreened diversions have a broad impact on the system. Screening or relocating the diversions would reduce the impacts on the populations of more than just the two species selected for this analysis.

Screening Technology

Prevention of the loss of juvenile fish, that is fish larger than three-quarters of an inch in length, is readily attainable. Perforated plate with an opening of 5/32" will protect all chinook salmon, steelhead rainbow trout, American shad, and striped bass larger than 3/4" in length. Alternately, continuous slot material with a 3/32" slot width will attain the same results. Of these, the profile wire continuous slot material has been identified as the slowest to clog, requiring the least maintenance, and thus would be preferable.

Screening technology to protect eggs and larvae is available, however, its cost and complexity makes it an unlikely solution to this problem. An alternate solution would be to develop an overland water supply from outside the striped bass nursery area for the Delta farms. However the cost of such a solution would be high and it is unlikely to be politically acceptable. Further, the reduction in instream flows which would accompany this solution would be undesirable.

TABLE 3

Summary of Striped Bass Evaluations

	Eggs/acre-foot	Young/acre-foot
Heubach (MS)		
Contra Costa Canal		
1972		207.38
1973		24.44
Allen (1975)		
Sherman Island		
1972	2467	641.42
State Fish Protective Facility		
1972		519.87
1973		360.49

Cost figures for a number of recent screens were obtained. From these figures, it appears an estimate of $1,000 per cfs would be reasonable for a program such as we are contemplating. Using this figure and the estimates of unscreened water being diverted developed earlier, a total cost of 23.5 million dollars would be required (Sacramento 12 million, Delta 4 million, and San Joaquin 7.5 million dollars).

CONCLUSION

To summarize the results, we have established that losses are occurring at unscreened diversions in the Sacramento-San Joaquin Estuary and its tributaries and that these losses are a substantial detriment to the resources.

Screening the diversions identified in this report would be a monumental task and some source of funds other than the Fish and Game Preservation Fund would have to be developed. Technology is now available to effectively eliminate the loss of salmonids and a program to screen these diversions could be rather quickly initiated. Unfortunately, the limited technology available to screen striped bass eggs and larvae is both more complex and more expensive. Alternatives to screening would require providing an overland water supply to the users in the striped bass nursery area.

The problem then, is whether to screen several thousand diversions ranging in size from 1½" to 50" in diameter and how to implement such a program. The technology is available to protect a large proportion of the resource presently being lost, although the operation and maintenance of these structures would be a major endeavor. Such a program could be implemented under existing legal authority if a source of funding could be developed. Alternatives which include a finding by the U. S. Army Corps of Engineers or the State Water Resources Control Board that the present method of diversion was unreasonable would, in the opinion of DWR Legal Counsel, result in the Department of Fish and Game bearing the full costs of meeting the new requirements on existing diversions. Finally, new legislation could be introduced to achieve these objectives.

Major unscreened diversions which require attention include Sunset Pumps on the Feather River, the Tisdale Diversion on the Sacramento River, and the Contra Costa Canal Intake in the Delta. The first two have already been scheduled for screening by the Department and the Contra Costa Intake will be covered by its proposed relocation to Clifton Court Forebay. Other diversions of concern include the Tehama-Colusa Canal intake at Red Bluff and the existing State and Federal export pumps in the south Delta. Negotiations are presently underway to rescreen the Tehama-Colusa Canal intake and should be completed as soon as possible. For the purposes of this report, we shall assume the Peripheral Canal fish screens will solve the south Delta problems.

While these programs are underway, we believe diversions in the Delta should be targeted and screened. Of the diversions studied, the Ryer Island Superintendent, identified by the USFWS, would be most appropriate for a beginning. Other Delta diversions, in order of size and location, could then be screened as funds become available for installation, operation, and maintenance. The program should concentrate on the Sacramento River side to start with.

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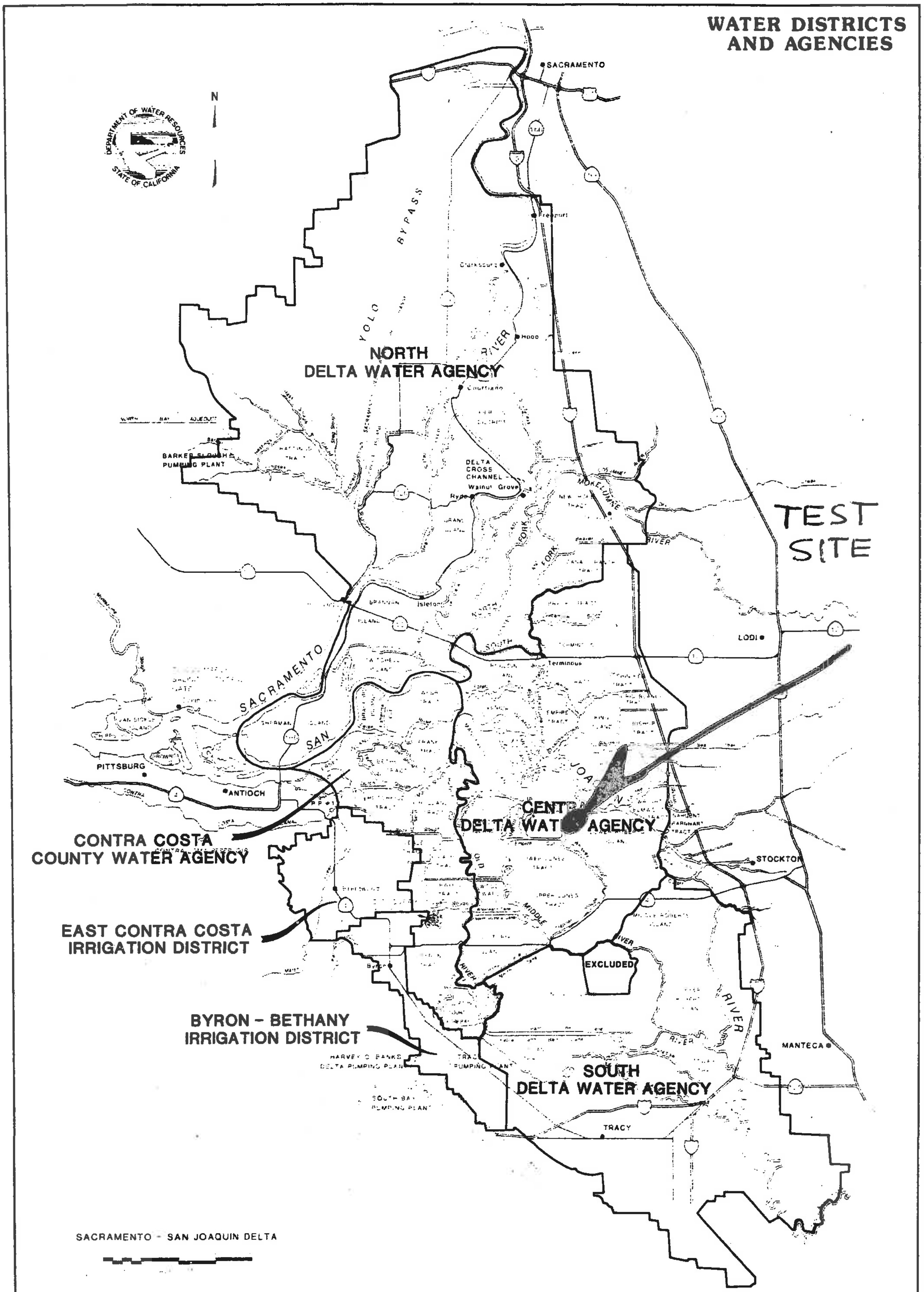
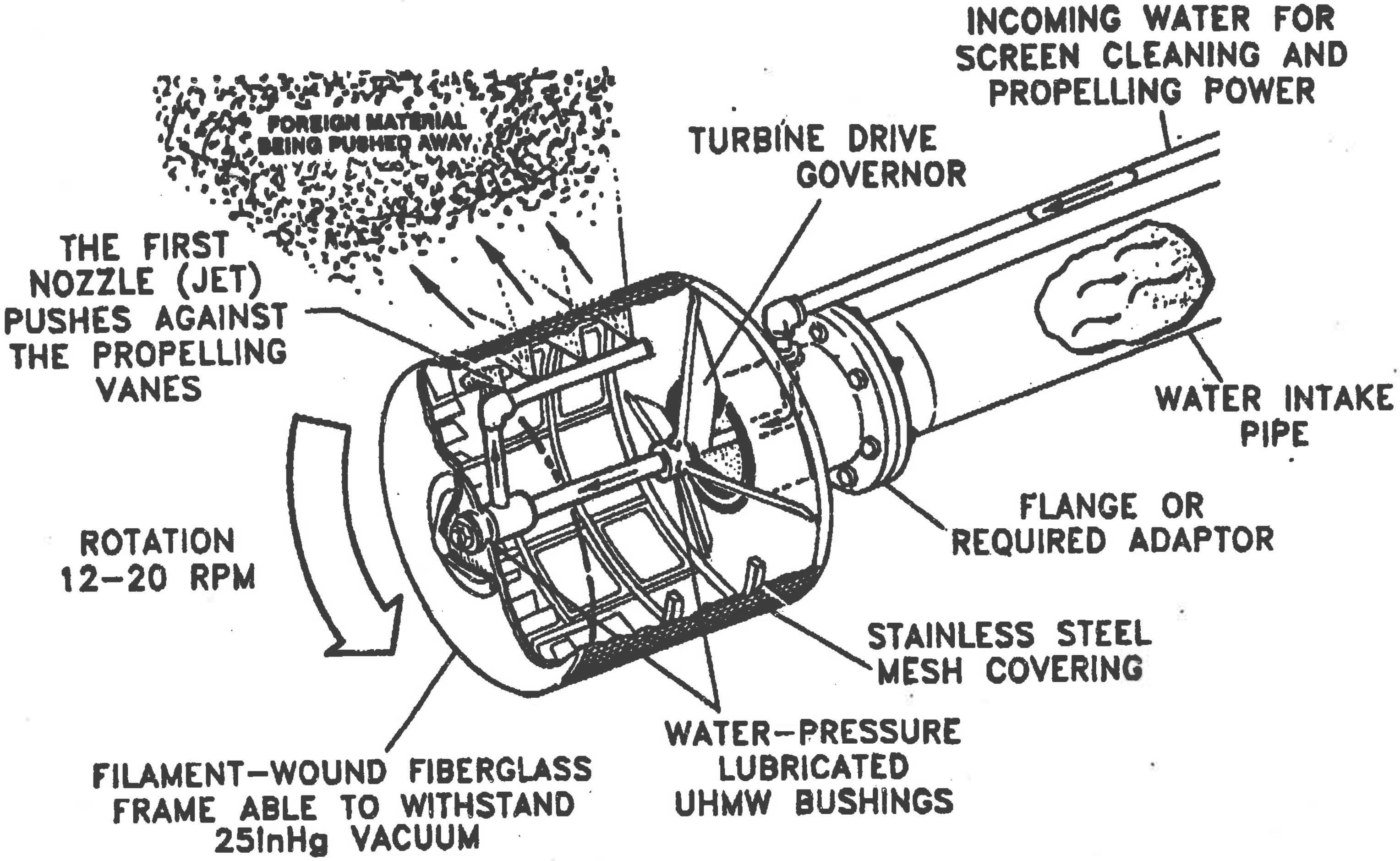


WRINT CDWA EXHIBIT 5

LAKOS IPC SERIES

SELF-CLEANING PUMP INTAKE SCREENS



The Lakos Self-Cleaning Pump Intake Screen with its internal backwash cleaning system will keep the filtering mesh cover free of all waterborn debris (debris that would plug an ordinary strainer).

The backwashing action and power to rotate the screen drum is provided by a turbine over the intake pipe and by a line from the pump discharge. This line supplies water to a stationary spray bar inside the drum as shown in the drawing above. One metered jet hits a series of driving vanes causing the screen to rotate at 12-20 RPM. The other jets blast the accumulating debris off the screen surface and keeps pushing it away in one specific direction.

SELF-CLEANING PUMP INTAKE SCREENS IPC SERIES								
MODEL	MAXIMUM FLOW RATE		SCREEN MESH SIZE	OUTLET PIPE		BACKWASH RETURN LINE CONNECTION	SHIPPING WEIGHT	
	USgpm	m^3/hr.		In.	mm		Lbs.	kg.
IPC1415-09	600	136	9	6	152.4	1 1/4"	31	14.0
IPC1415-30	500	114	30	6	152.4	1 1/4"	31	14.0
IPC1424-09	1100	250	9	10	254.0	1 1/2"	60	27.3
IPC1424-30	800	182	30	10	254.0	1 1/2"	60	27.3
IPC2424-09	1900	431	9	12	304.8	1 1/2"	75	34.1
IPC2424-30	1300	305	30	12	304.8	1 1/2"	75	34.1
IPC3424-09	2700	613	9	16	406.4	2"	100	45.5
IPC3424-30	1900	432	30	16	406.4	2"	100	45.5

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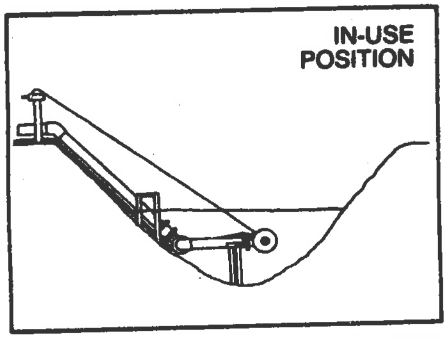
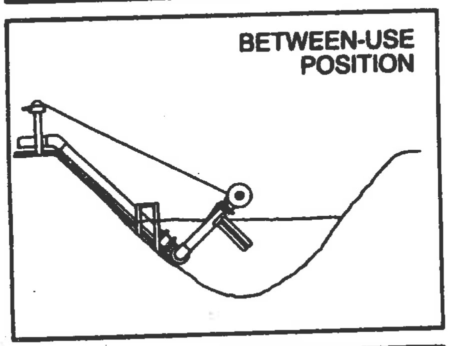
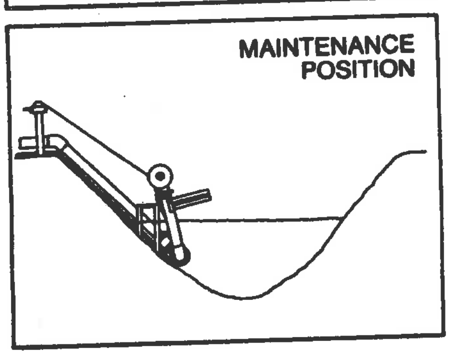
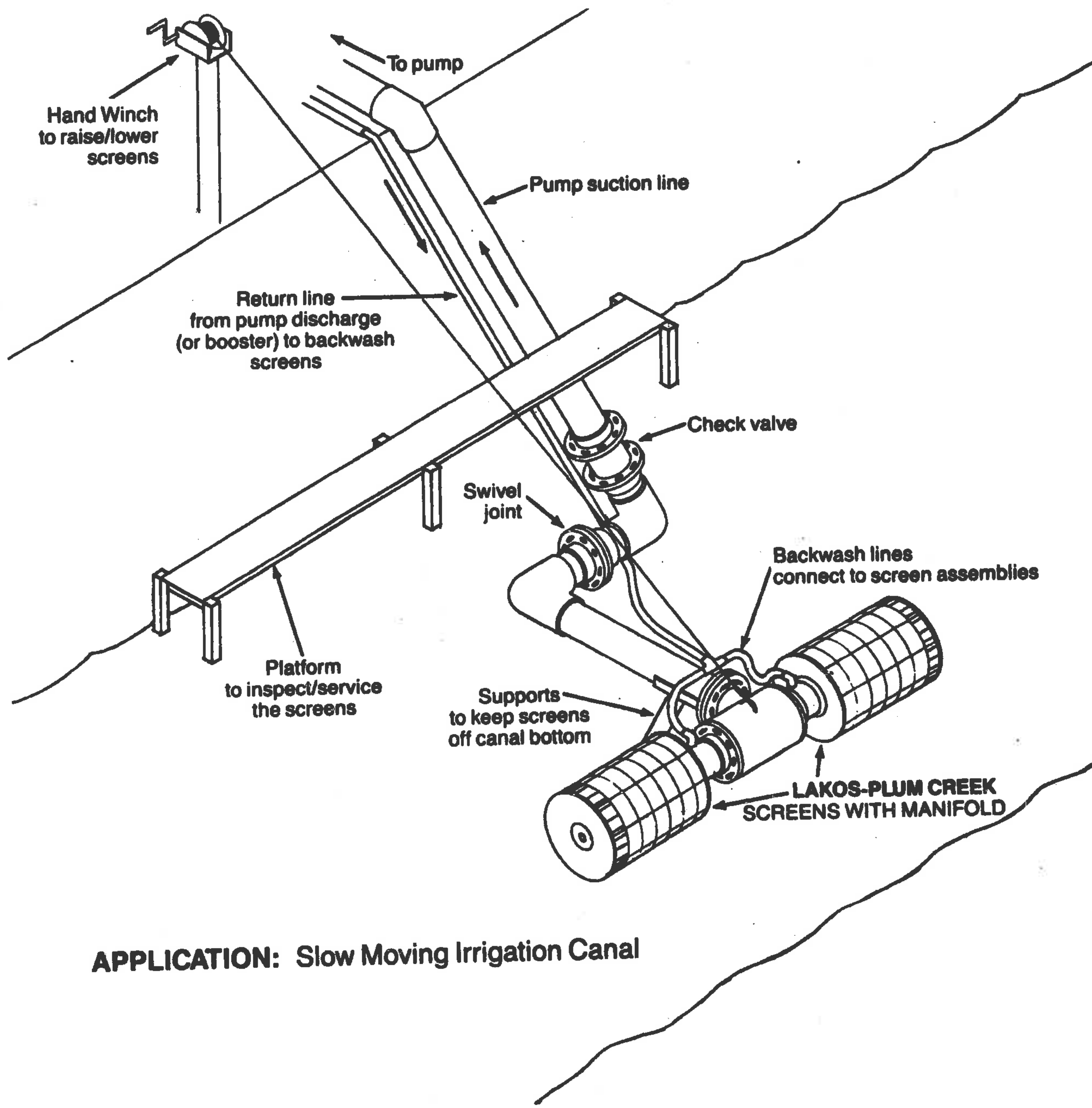
APPLICATION Sketch

LAKOS·PLUM CREEK









APPLICATION: Slow Moving Irrigation Canal

RESUME

Dante John Nomellini

Born: November 22, 1942, Stockton, California

Attended local grammar school and high school.

Awarded Bachelor of Civil Engineering Degree from the University of Santa Clara in June, 1964.

Awarded Degree of Juris Doctor from the University of California, Boalt Hall, School of Law in June, 1967.

Admitted to the State Bar of California December 21, 1967.

Actively working in the field of water rights since 1968.

Presently serving as one of the attorneys for the Central Delta Water Agency and as a member of the Advisory Water Commission of the County of San Joaquin.

END OF DOCUMENT

INTERIM HEARING
OF THE
BAY DELTA PROCEEDINGS

Rebuttal Testimony of Dante John Nomellini

August 1992

Fish Screens

In my capacity as manager and co-counsel of the Central Delta Water Agency I have direct responsibility for a Delta-Siphon Fish Screen Test Project now underway on McDonald Island. Exhibit WRINT CDWA Ex. 5 shows the location of such project. Exhibit WRINT CDWA Ex. 6 shows the type of screen utilized and Exhibit WRINT CDWA Ex. 7 the configuration of the installation. Somewhat unique to this project is the hinge which allows the screen manifold to be easily lifted out of position while leaving the siphon fully operational. The hinge greatly reduces the risk of crop loss due to screen plugging. Although we hope to continue our test a number of preliminary conclusions are apparent.

1. Technology and hardware appears to be available to screen small fish (1 inch or greater in length) but does not appear to be available to screen eggs and larvae. See also Exhibit WRINT CDWA Ex. 1, pgs. 27 and 37 and Exhibit WRINT CDWA Ex. 4 pg. 9.

2. A major cost component for fish screens is bringing electrical power to the site.

3. The average cost of installing a self cleaning fish screen for Delta diversions is probably upwards of $50,000.00 per site. Operation and maintenance costs are not yet known.

4. The DWR - Sacramento - San Joaquin Delta Atlas dated August 1987 page 49 shows approximately 1600 irrigation diversions. The cost of screening just the small fish at all these locations appears to be about $80,000,000.00.

5. Some areas of the Delta have greater concentrations of eggs, larvae and fish than others. (See Exhibit WRINT CDWA 1 pg. 29 and Exhibit WRINT CDWA 3.

6. There is a substantial variation in the diversion potential of fish and eggs among diversion locations in the same area. See Exhibit WRINT CDWA Ex. 2 pgs. 4 and 5. Possible important variables could be depth of intake, configuration of intake, channel flow characteristics and desirability of habitat near the intake.

7. There is a substantial variation in the time and duration of diversions depending upon crops and extent of area served. By way of example the siphon on McDonald Island used for our fish screen test project was operated for only four (4) days for irrigation purposes. The field served by the siphon was planted to wheat which had adequate moisture from seepage and rainfall except in the later part of May when irrigation water was applied during a four (4) day period.

8. California Law requires the Department of Fish and Game to bear the cost of screening agricultural diversions in the Delta which are less than 250 cfs. See Exhibit WRINT CDWA Ex. 1 pg. 37 and Exhibit WRINT CDWA Ex. 4 pg. 2 paragraph 4.

9. More study is needed to determine which diversion points in the Delta significantly affect fish, eggs or larvae and whether it is cost effective to screen or relocate the high impact diversions.

10. More study is needed to determine whether or not it is possible to monitor the movement of fish, eggs and larvae and thereby develop a program to alter the timing of diversions at high impact locations in order to reduce diversions of fish through agricultural diversions.

<u>Growth and Development in Areas to Which Water from Delta is Exported</u>.

Exhibit SWC 3b figure 9 shows that the desert area per household use is about 65% higher than the coastal household use and about 30% higher than the inland valley household use. At page 13 of the same exhibit it is explained that growth in the desert area is expected to be higher than in the other two areas. The absence of growth planning is apparent. Assuming the present projected demand can be met without further destruction of northern California what is the plan for the future? How much desert can we allow to be developed? If the future demand is to be met with desalted water then why allow further destruction of northern California as an interim solution?

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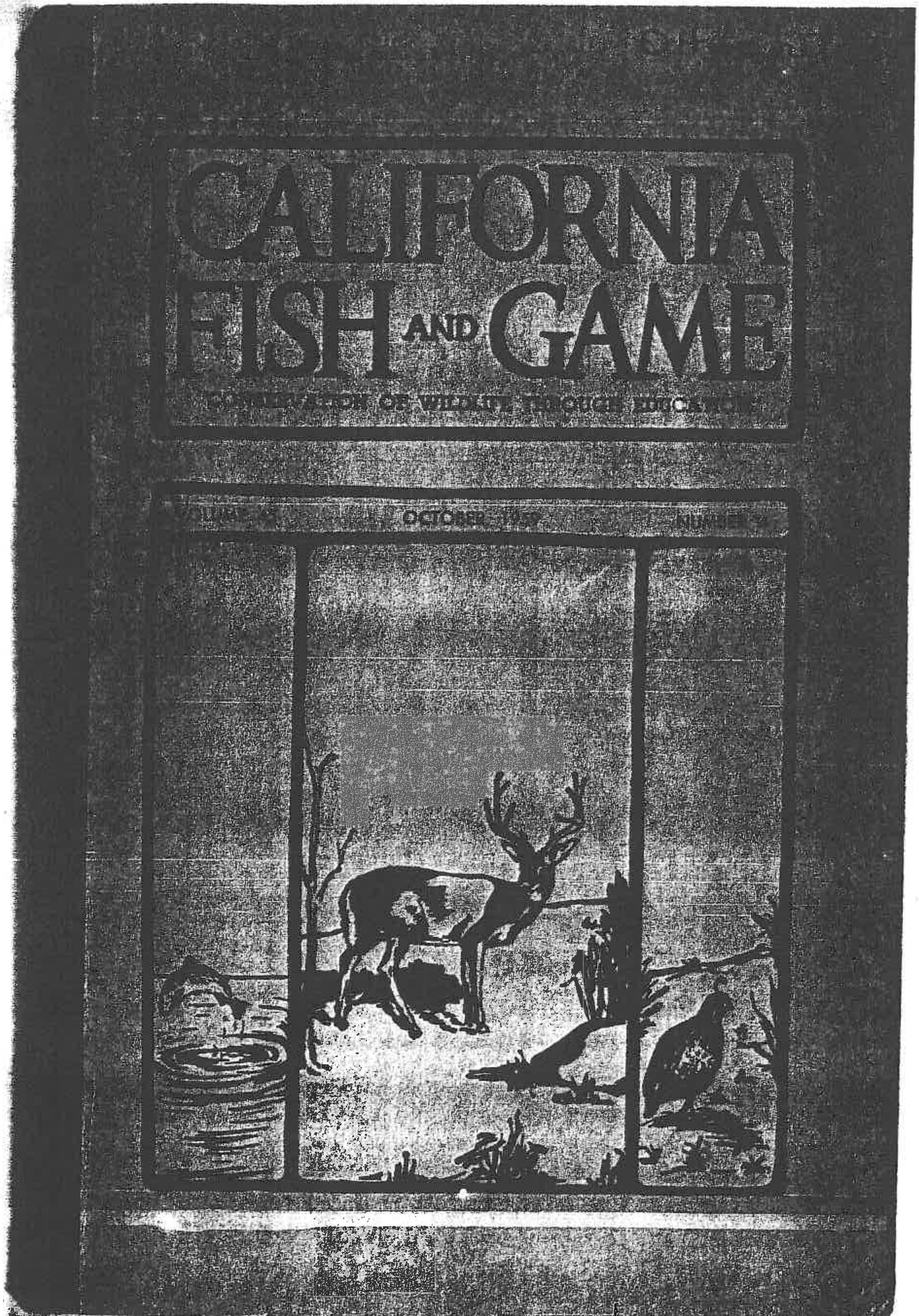

WRINT-CDWA Ex. 10

TABLE OF CONTENTS

A SURVEY OF ANADROMOUS FISH LOSSES IN IRRIGATION DIVERSIONS FROM THE SACRAMENTO AND SAN JOAQUIN RIVERS[1]

RICHARD J. HALLOCK and WILLIAM F. VAN WOERT[2]
Inland Fisheries Branch
California Department of Fish and Game

INTRODUCTION

In spite of the encroachment of modern civilization, California's Central Valley continues to embrace one of the most important king salmon (*Oncorhynchus tshawytscha*) spawning areas in the world. A sizable steelhead rainbow trout (*Salmo gairdnerii gairdnerii*) population also spawns annually in the Sacramento River system.

There are now more than 900 irrigation, industrial, and municipal water supply diversions above the Sacramento-San Joaquin River Delta from stream sections utilized by salmon, steelhead, and other anadromous fishes as migration routes to and from the sea. Most of these diversions are for irrigation. In the Delta there are many additional diversions. Along the Sacramento and San Joaquin rivers water enters the numerous canals and ditches primarily through pumping stations, which vary in size from single two-inch diameter pumps to installations of 10 pumps ranging in size from 42 to 100 inches in diameter. Water is diverted by gravity as well as by pumps into many ditches leading from the tributary streams. In addition, there are a large number of siphons, up to 60 inches in diameter, in the Delta. Very few of these diversions are screened to prevent fish losses, although trash grids at the headworks of many canals and on pump intakes prevent losses of adult fish.

Over the years, considerable experimentation on the development of mechanical and electric fish screens to prevent anadromous fishes from being destroyed in diversions has been carried out in California. Perhaps even more study has been directed towards determining the time of year when juvenile king salmon migrate from Central Valley streams to the sea. As early as 1899, fyke nets were fished for this purpose in the lower Sacramento River at the head of Georgiana Slough (Rutter, 1903). A 40-year period lapsed after this early fyke netting, only to be followed—from 1939 until the present—by a series of systematic netting operations, both by the California Department of Fish and Game and the United States Fish and Wildlife Service, to study fingerling salmon migrations.

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[1] Submitted for publication January, 1959. This work was performed as part of Dingell-Johnson Project California F-7-R, "Sacramento-San Joaquin River Salmon and Steelhead Study," supported by federal aid to fish restoration funds.
[2] Both authors have transferred to Marine Resources Branch since this report was written.

Although considerable information has thus far been obtained on the migration times of juvenile Sacramento-San Joaquin River salmon and on how to prevent them from entering many types of ditches, particularly gravity diversions, only a comparatively moderate amount of study has been directed toward measuring actual fish losses at the various types of diversions, especially those utilizing pumps. Accordingly, in the spring of 1953 the California Department of Fish and Game initiated a survey of the multitude of unscreened diversions along the Sacramento and San Joaquin rivers and of the overall juvenile salmon and steelhead lossess occurring in them. While the task of measuring fish losses at each diversion would have been a monumental one and beyond the scope of the study, specific information was sought for typical diversions so that data obtained might be applied to other similar diversions. No attempt was made to study other than existing conditions, i.e., no experiments covering the effects of various theoretical diversion intake types on fish losses, etc., were conducted. Information on certain diversions for which an immediate evaluation of fish losses was essential, particularly on Butte Creek, a tributary to the Sacramento River, was also sought.

In 1953 and 1954 the diversion survey was centered along the Sacramento River between the cities of Redding and Sacramento. In 1955 the study was shifted to the San Joaquin River and into the Sacramento-San Joaquin River Delta. With an overall fish loss picture having been determined for the two principal rivers in the Central Valley,

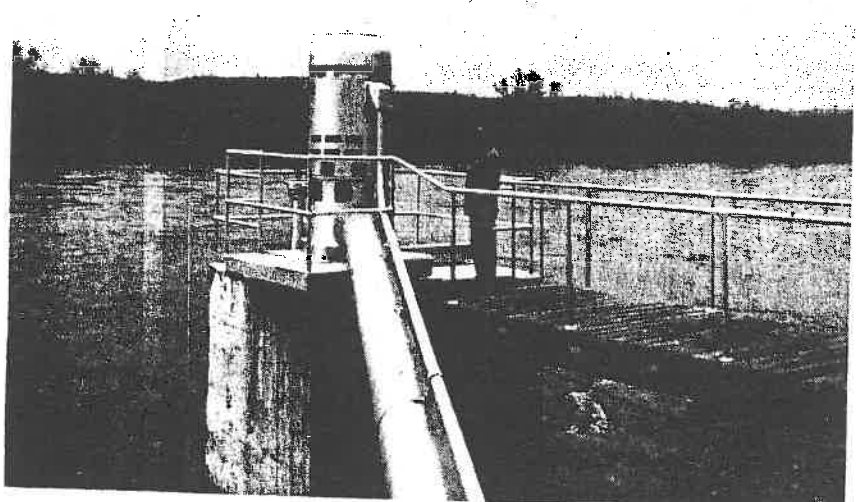

FIGURE 1. One of the Redding Municipal Water Supply pumps, a 14-inch diameter [illegible]

work in 1956 and 1957 was concentrated on Butte Creek. This report summarizes irrigation diversion fish loss data obtained during the five irrigation seasons from 1953 through 1957, with the major emphasis on fingerling king salmon.

ACKNOWLEDGMENTS

Many people contributed to the irrigation diversion survey. The authors are particularly indebted to Leo Shapovalov, Assistant Chief of the Inland Fisheries Branch, for guidance during the study and for invaluable assistance in the final preparation of the manuscript for publication. Several other members of the California Department of Fish and Game also contributed vitally to the success of the program. Harry A. Hanson instigated the study and, along with Elton D. Bailey and Don A. LaFaunce, did much of the work during the first two years. Mr. Bailey also reviewed the manuscript and offered many helpful suggestions. John E. Riggs was in charge of field work during the last three years of the study.

STUDY PLAN

The original plan called for a listing of pumps along the Sacramento and San Joaquin Rivers, grouped according to factors thought to influence fish losses, such as size, type, depth and position of intake, etc. Next, the total seasonal loss of juvenile salmon and steelhead was to be determined for pumps selected as representative of each group. Other pumps would then be evaluated on the basis of results from those tested. It was also thought losses at the selected pumps could be weighted by the number of similar pumps in each group, to provide an estimate of the total seasonal losses in all pump diversions in the study area. The selected pumps from each group were to be drawn only from those which were thought to operate continuously during the irrigation season and which the survey had indicated could be sampled with fyke nets. A similar study, time permitting, was planned for Butte Creek.

This plan, however, was not strictly followed because some of the selected pumps which had operated continuously during the irrigation season while the pump classification surveys were being made did not operate or operated only intermittently during the season when the diversion sampling took place. In addition, limitations in the availability of both men and equipment reduced the area in which the studies could be effectively carried out, and made it impractical to sample all of the selected diversions along the entire Sacramento and San Joaquin Rivers above the Delta.

The study plan then of necessity was altered to include only an overall survey and a general evaluation of fish losses in the diversions, with specific fish loss data to be obtained for certain diversions under consideration for screening in the near future.

To determine this general picture of the losses through pumps, the areas between Princeton and Meridian on the Sacramento River and between Stockton and Patterson on the San Joaquin River were selected.

The numbers of fish passing through pumps were obtained by operatdetermine net efficiencies. The sampling procedure consisted of setting one or more fyke nets in the canal as close to the discharge outlet of the pump as possible. The distance between the discharge outlet of the pump and the fyke net varied from a few feet to as much as one-half mile, but generally was less than 150 feet.

SAMPLING NETS

Riffle fyke nets of the type described by Hallock, Warner, and Fry (1952), and used by them to capture downstream migrant king salmon in the upper Sacramento River, were used to sample the discharge into

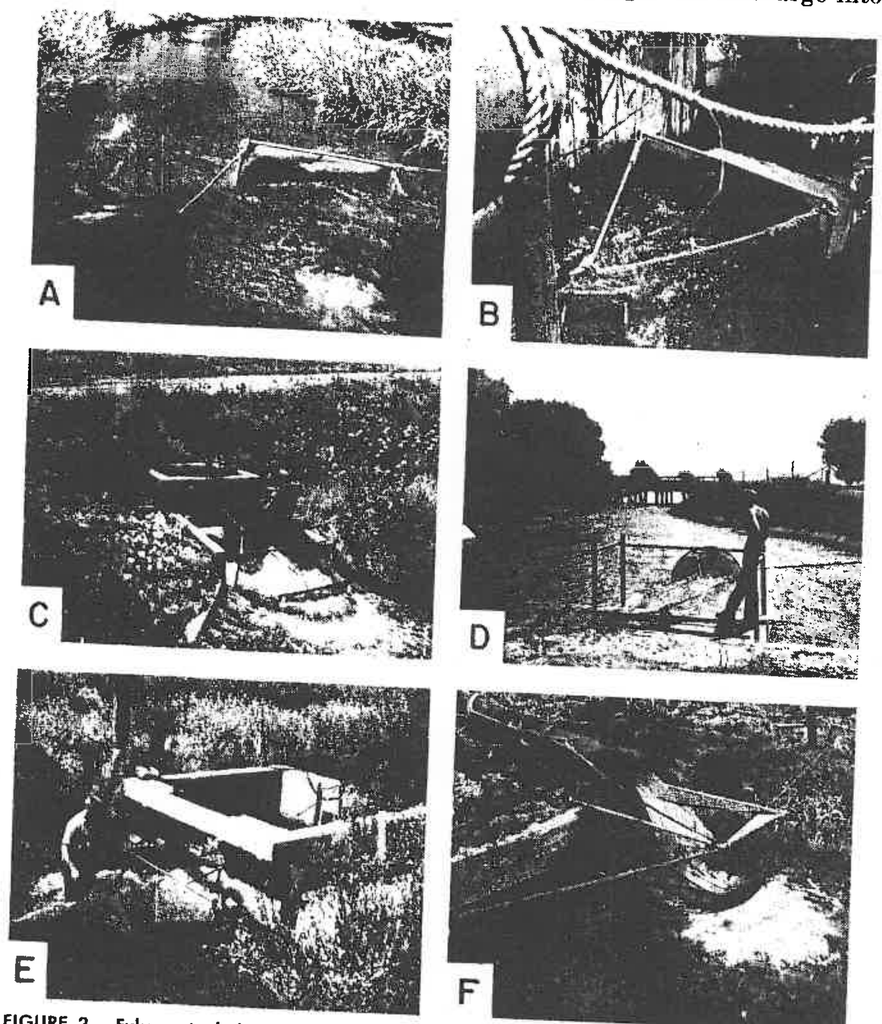

FIGURE 2. Fyke nets being fished in Sacramento River irrigation diversions during 1954, showing various methods of setting the nets. A, Hollis Sartain; B, Olive Percy Davis et al.; C, Wayne Hall; D, Sutter Mutual Water Company, Tisdale pumping plants No. 1 and No. 2; E, W. A. Larner; F, Tisdale Irrigation and Drainage Company. *Photographs A and B by Don A. LaFaunce; C, D, and F, by John E. Riggs; and E, by Elton D. Bailey.*

a number of the smaller ditches. These nets were made of one-half-inch stretched mesh cotton webbing hung on three rectangular metal frames. There was a 3-foot by 5-foot rectangular opening at the large end, and they were about nine feet long. A funnel of webbing tapered to a nine-inch square opening was installed inside the net at the second frame, 21 inches from the large open end. The pot of the net was formed by gathering together the webbing at the small open end and securing it with several turns of heavy twine.

Round fyke nets of slightly greater size were used to sample the discharge in the largest canals. These nets were also made of one-half-inch stretched mesh cotton webbing hung on three metal rings. They were 5 feet in diameter at the large open end and about 10 feet in length. A funnel of webbing, tapered to a round opening 11 inches in diameter, was installed inside the net at the second ring, 30 inches from the large open end. The pot of the net was formed in the manner described for the rectangular nets.

Simple bag nets of several shapes and sizes were used to sample the high velocity discharge from large pumps. These nets were made of one-half-inch stretched mesh cotton webbing, and had no funnels. One type was hung on a frame 4 feet square and had a bag 8 feet long. A second type was hung on a ring 3 feet in diameter, and also had a bag 8 feet long. The bag on the 3-foot circular net was later lengthened to about 10 feet, so that the pot could be moved to one side of the main discharge current to provide a resting place for the captured fish.

Near the end of the sampling period a round fyke net patterned after the one used by Schoeneman and Junge (1954) was made especially to sample the discharge from a 24-inch pump. This net consisted of a funnel of one-half-inch stretched mesh cotton webbing, a canvas pipe 8 feet long, and a live box of 2-inch cedar boards and hardware cloth (six meshes per inch). The funnel was 7 feet long. It tapered from 30 inches in diameter at the open end to 8 inches in diameter at the small end. The canvas pipe was eight inches in diameter. It had a metal ring sewn in at one end and a square metal frame at the other. The small end of the funnel and the round end of the pipe were sewn together. The live box was 18 inches wide, 24 inches high, and 36 inches long, with ends and framework of cedar, and was covered on the sides and bottom with hardware cloth. The box had a hinged lid, also covered with hardware cloth. One end of the live box had a rectangular opening at the top 7 inches wide by $7\frac{1}{2}$ inches deep, to receive the square end of the canvas pipe which slipped into a slot just inside the live box opening. The canvas pipe and the live box were fastened together by slipping the square end of the canvas pipe into the slot provided for it, closing the lid, and securing it with a wing nut. A baffle board was placed in the bottom of the box to provide a resting place for the small fish captured. It was usually necessary to place a weight in the bottom of the box to keep it upright. With the live box placed in still water, the fish were kept in essentially the same condition as when they came through the pump. By opening the lid and detaching the canvas pipe, the live box was easily carried to shore and emptied.

Another net of this type was used in 1955. It included a funnel 9 feet long, tapering from a 2-foot by 4-foot rectangular opening at the large

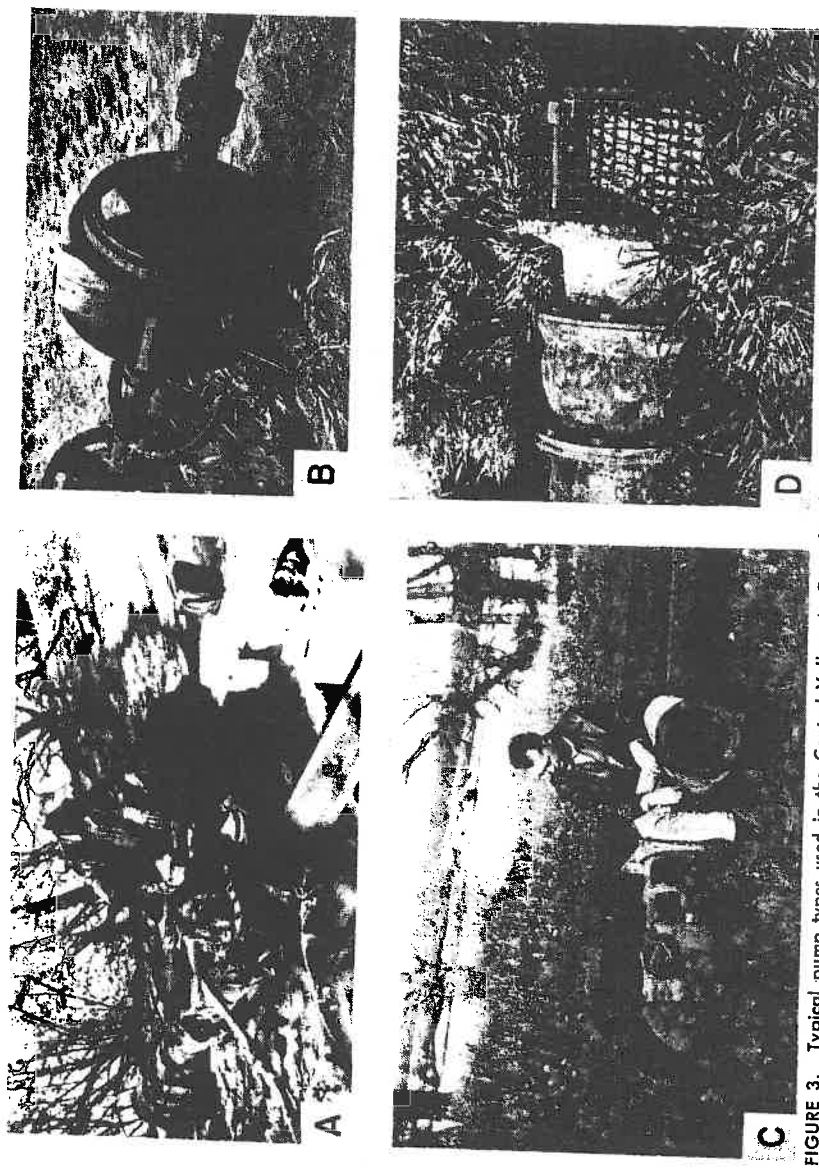

FIGURE 3. Typical pump types used in the Central Valley. A, Centrifugal pump, showing common installation method for single pumps; B, impeller from a centrifugal pump; C, screw-type pump; D, intake of a screw-type pump. Photographs A, by Elton D. Bailey; B, by William F. Van Woert; C, by Don A. LaFaunce; and D, by John E. Riggs.

end to 9 inches square at the small end. The canvas pipe was omitted, and the small end of the funnel slipped directly into a slot in the live box. The live box was made of aluminum perforated plate with $\frac{5}{32}$-inch round holes on $\frac{7}{32}$-inch centers.

PUMP TYPES

Practically all irrigation water is diverted from the Sacramento and San Joaquin rivers by pumps of one type or another.

The high-speed rotative units are of two main types: One utilizes an impeller, or runner, similar in shape to a ship's propeller, and is called a screw-type pump. The impeller is simply an inclined plane which when rotated slices under the water and lifts it. This type of pump has the advantage of being able to deliver more water than the second or centrifugal type of impeller, for any given size.

The centrifugal impeller pump operates differently from the screw type in that water is thrown out of it, into the discharge outlet, by centrifugal force. One advantage of the centrifugal pump is that it will continue to give fair service even after the impeller parts are considerably worn (of course, with some loss of efficiency). The drive shaft of a centrifugal pump may be mounted either vertically or horizontally, although horizontal mounting is the more common.

A few of the horizontal centrifugal pumps and most of the vertical ones are called turbines because they have special cases or housings which differ materially from the simple volute or spiral-shaped case. In turbines the case, or impeller housing, contains stationary vanes which help direct the water to the discharge pipe, or to the next stage in the event it is a multiple stage pump. These vanes mark the pump as a turbine, whether the impeller be of the centrifugal or screw type. In some instances, the runners or impellers of turbines are designed so they will have some of the properties of both the screw-type and centrifugal-type pumps. These are called combination or mixed flow pump impellers. They combine the high discharge capacity of the screw impeller with other desirable features found only in the centrifugal pump.

SACRAMENTO RIVER

Salmon Migration

Adult king salmon migrate into the upper Sacramento River system during all months of the year, but there are three periods each year when the migration is greatly intensified. These peaks in the migration represent three distinct runs of fish, while most of those moving upstream between the peaks are apparently either early or late segments of one of the three main runs: winter, spring, and fall (Hallock, Fry, and LaFaunce, 1957).

The movement of winter- and spring-run salmon is fairly continuous in the lower river, between early November and the last of May, but with considerable overlap, and it is difficult to distinguish clear-cut peaks in their migration. However, even though they move up the river at about the same time, these two groups of fish separate in the upper river as dictated by their spawning characteristics. Most of the winter-run fish spawn during May and June, in the upper portion of the main stem of the Sacramento River, between Anderson and Keswick Dam;

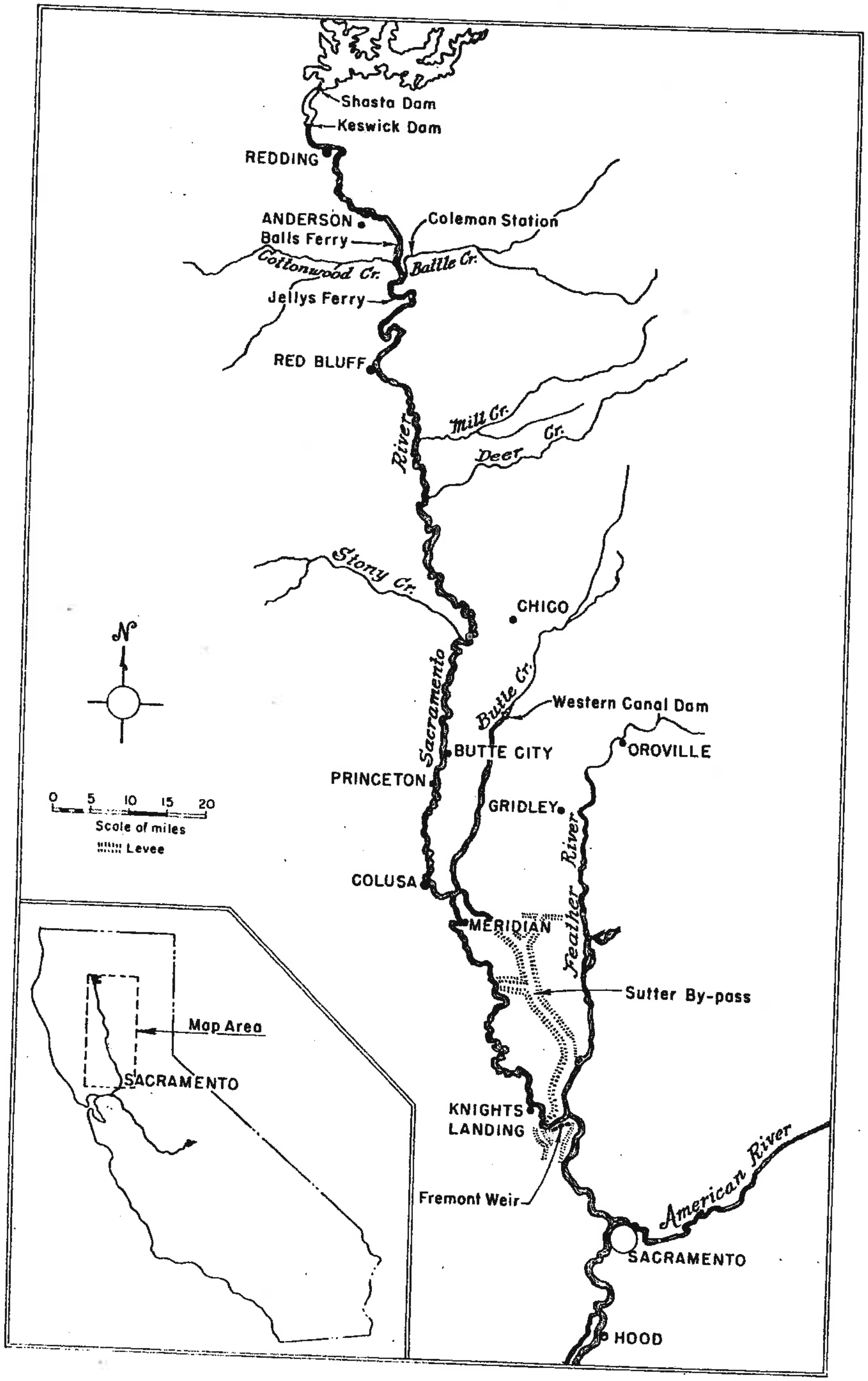

FIGURE 4. Map of the Sacramento River system, showing the areas where irrigation diversions were sampled.

however, in some years they also spawn in tributary streams. Spring-run fish spawn principally in late August, September, and early October. Spawning takes place primarily in the upper reaches of the Sacramento River above the City of Red Bluff, and in the higher reaches of the larger tributaries such as Butte, Deer, Mill, and Battle Creeks. The bulk of the fall run, which is larger in numbers than the other two combined, moves into the upper river between the middle of August and the early part of November. Most of the fall-run fish spawn between the middle of October and the latter part of December, with the greatest spawning activity taking place near the middle of November. Spawning takes place in the Sacramento River from a short distance below Chico to Keswick Dam, and also in the lower reaches of practically all suitable tributary streams.

The young of the Sacramento-San Joaquin king salmon either migrate to the ocean as soon as they reach the fingerling stage (when the yolk sac is absorbed and the fish can swim freely) or remain in the stream for about a year before going to sea. Between 80 and 90 percent of the young salmon go from fresh water to the ocean during their first year (Clark, 1929).

It is known that tremendous numbers of young salmon move down the Sacramento each winter and spring. Although there are no reliable estimates of the total numbers of migrants, partial figures are available for some years. For example, in the course of a marking experiment conducted by the California Department of Fish and Game in 1950, salmon were captured in the Sacramento River near Red Bluff, marked at the United States Fish and Wildlife Service's Coleman Fisheries Station on Battle Creek, and released in the Sacramento River at Jelly's Ferry. Marked fish were recaptured in sufficient quantity downstream at Red Bluff to provide a rough estimate of the total numbers passing the trapping site. According to figures based on recoveries following release of over 187,000 marked fish, close to 13,000,000 salmon moved downstream past Red Bluff between February 18 and March 10, 1950.

King salmon fry in the Sacramento River tend to move downstream at the time of seasonal increase in runoff. Salmon migration studies by the United States Fish and Wildlife Service in the Sacramento River at Balls Ferry, including 10 seasons of fyke netting between 1944 and 1953, show a measurable downstream movement between early October and the latter part of May in most years. The majority of the young salmon, however, migrate between early December and late April. The peak of the downstream movement varies from year to year; it may occur in late December, as in 1946, or even in late February, as in 1952. However, more often than not, two or even three peaks are evident between January and early March. Results of the 1944-1953 salmon migration studies at Balls Ferry are in agreement with the findings of studies made near the same location in 1899 (Rutter, 1903). Over 15,000 seaward migrants were handled between January 6 and April 25, 1899, and it was found that the height of the migration occurred between February 1st and 15th. Hanson, Smith, and Needham (1940) also noted a fall migration past Redding, finding a peak in mid-September of fish three to four inches long, thought to be salmon, which remained in the upper river (now blocked by Keswick and Shasta dams) over the summer.

Salmon migration studies also have been made in the lower Sacramento River. Fyke netting was carried out in the Sacramento River near Hood in 1899, 1940, 1941, 1947, and 1948. Findings were essentially the same in each of these years. Young king salmon were taken between mid-December and early June, with maximum numbers migrating during February and March, when as many as 80 percent of the total were taken.

Horizontal and Vertical Distribution of Downstream King Salmon Migrants

Between 1949 and 1953 tow net and push net operations by the United States Fish and Wildlife Service in the Sacramento River near Red Bluff revealed that during times of normal stream flows fingerling salmon migrate downstream at depths varying from the surface to four feet, moving in greatest numbers two to four feet under the surface. It was further demonstrated that the juvenile salmon migrate downstream fairly uniformly across the river but vary somewhat from midstream to the shores with changing water levels and velocities.

This is in accord with results of fyke netting operations carried on during the spring of 1950 by the California Department of Fish and Game in the Sacramento River just below Red Bluff. At that time 22 fyke nets were being fished side by side across the river over about half its width. Fingerlings were captured in all nets, with a few more fish usually being taken in the nets farthest from the shore.

During the 1954 netting operations in Sacramento River diversions it was discovered that during periods of high water and with flood conditions prevailing the fingerlings are spread throughout the river, and are to be found at considerable depths as well. In one instance near Colusa, fingerlings were being pumped in quantity into a canal when the pump intake was close to 20 feet under the river surface.

Irrigation Season

Records for the 10-year period, 1945-1954, show that the irrigation season along the Sacramento River between Sacramento and Redding extends from March to October (Figure 5). However, only 0.5 percent of the total seasonal volume used for irrigation is diverted in March and 8.4 percent in April. Seventy-six percent is diverted from May through August inclusive. An average of about 1,831,000 acre feet of water is diverted annually in this river section, which means that during the season an average of about 3,768 cubic feet of water per second leaves the river through the multitude of diversions during the entire eight-month season.

Fingerling Salmon Migration and the Irrigation Season

Individually the great majority of the pumping plants are small, and divert but a minor fraction of the Sacramento River flowing past their intakes. However, several of the larger ones do take enormous quantities of water, but usually late in the normal fingerling king salmon migration period. In 1954, the Glenn-Colusa Irrigation District diversion, which is the largest single diversion on the upper Sacramento, did not take water in February or March, but during April about 2.4 percent of the entire Sacramento River flowing past the intake was pumped onto the fields at this point. By May, 16 percent of the river's flow was

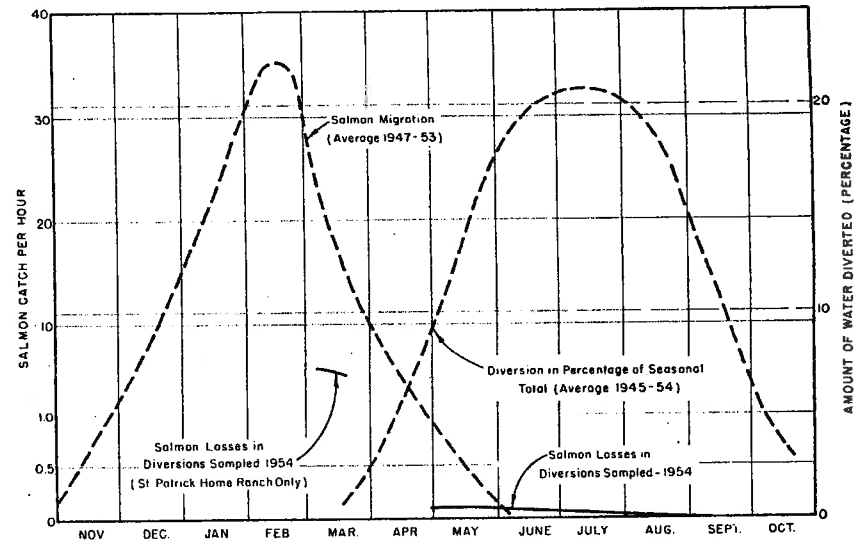

FIGURE 5. Comparison between times of the seaward migration of Sacramento River king salmon fingerlings, their losses in irrigation diversions, and the diversion of water for irrigation. The salmon migration was determined by fyke netting in the Sacramento River at Balls Ferry. Salmon losses were determined by fyke netting in irrigation diversions from the Sacramento River between Butte City and Knights Landing. The average diversion of irrigation water in percentage of the seasonal total includes data for the entire river between Sacramento and Redding.

being taken by this one diversion. Farther downstream near Meridian, the Sutter Mutual Water Company's large diversion took only 0.6 percent of the Sacramento River flowing past their pumps during April. However, during May, 10 percent of the river's flow was diverted.

A comparison between times of the annual seaward migration of juvenile salmon and the combined acre feet of water diverted by all pumps along the Sacramento River between Redding and Sacramento reveals that during most years the majority of the fingerlings have moved out of the upper river before the irrigation season gets into full swing (Figure 5). However, the migration tapers off through the spring and early summer, so some losses are to be expected each year during most of the summer months, particularly at the larger diversions. This is what occurred in 1954.

The one pump found to be operating in March, 1954, illustrated the potential danger of pumping, even during near-flood flows in the river, when fingerlings are migrating, since considerable losses of salmon occurred (Figure 5). Further reference to this pump, St. Patrick Home Ranch, appears in the section, "Diversions Sampled and Fish Losses."

The percentage of stream flow which is being diverted is perhaps of equal significance with the time when water is being diverted in determining salmon losses during the migration period. In 1954, less than 1 percent of the Sacramento River between Redding and Knights Landing was diverted in March, and less than 5 percent in April. However, by May, after most of the salmon had already migrated out of the upper river and into the Delta, about 25 percent of the river flow was diverted from this stream section.

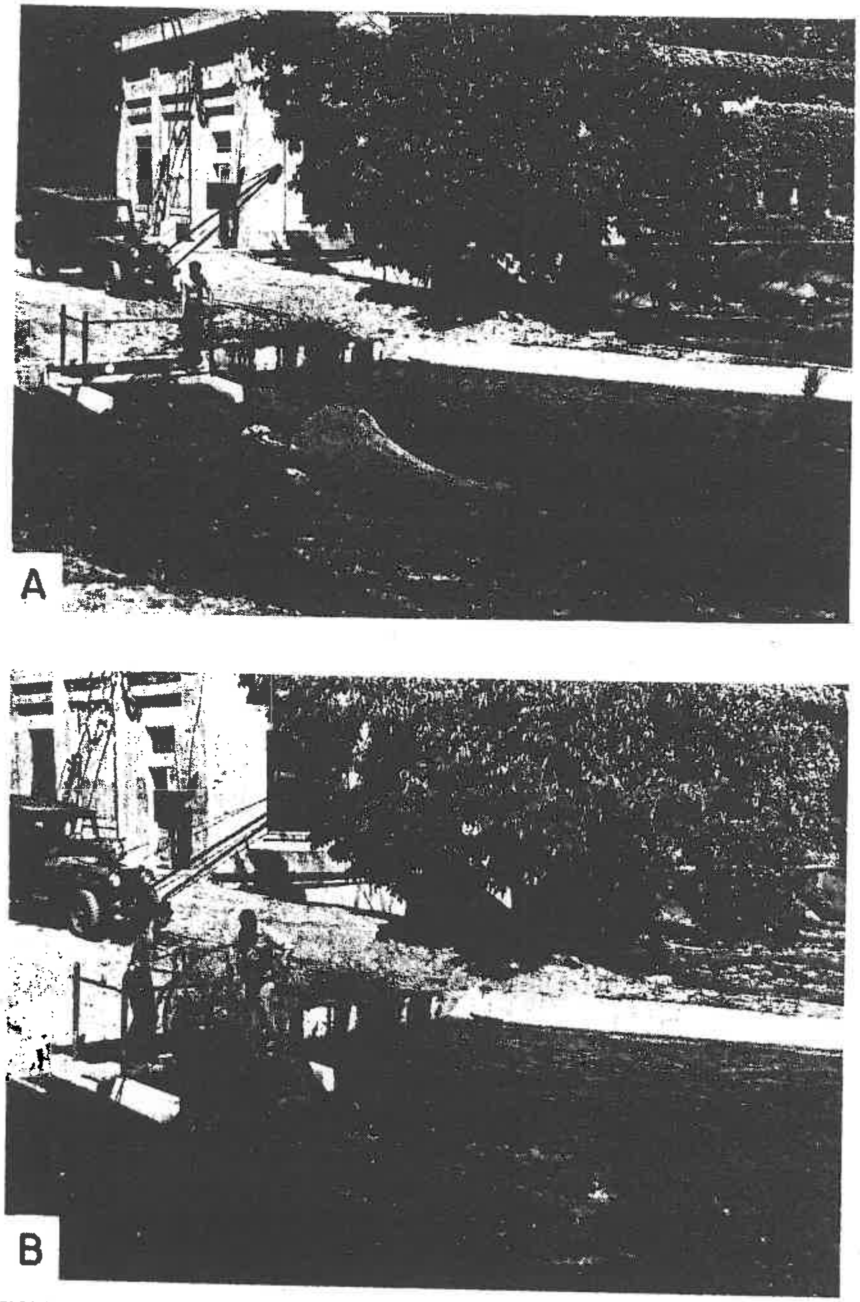

FIGURE 6. Fyke netting in the Sutter Mutual Water Company's Tisdale plants No. 1 and No. 2, Sacramento River, 1954. A, netting the discharge from two 48-inch diameter pumps; the discharge pipes from six 42-inch diameter pumps appear in the right background; B, putting net back in the canal after removing catch and cleaning; the jeep winch and hoist were used to remove the net from the water. *Photographs by John E. Riggs.*

Diversions Sampled and Fish Losses

In 1953 there were 335 separate diversions, utilizing a combined total of 448 pumps, along the Sacramento River between Redding and Sacramento, with the centrifugal-type pumps outnumbering the screw-type about 2 to 1. These pumps varied in size between 1¼ and 100 inches in diameter, with about 80 percent being from 6 to 24 inches in diameter. Eleven percent were larger than 24 inches in diameter. Preponderantly the diversions are single and double pump installations supplying water to limited acreages. However, along the river section between Knights Landing and Butte City, where the 1954 diversion sampling was conducted, there are also several larger pumping plants, including those of the Sutter Mutual Water Company (Tisdale plants No. 1 and No. 2), which utilize seven pumps ranging in size from 42 to 48 inches in diameter; Reclamation District No. 1,004, with three pumps from 30 to 50 inches in diameter; Provident Irrigation District, with five pumps from 24 to 42 inches in diameter; and the giant Glenn-Colusa Irrigation District diversion, with 10 pumps from 28 to 100 inches in diameter.

During 1953, initial surveys were made of 371 pumps, representing 294 separate diversions from the 246-mile section of the Sacramento River between Redding and Sacramento. At each pump site, information was obtained on factors believed to influence fish losses, such as size and type of pump, depth of intake, distance between intake and river bank, angle at which the intake pipe entered the water, velocity of flow past the intake, and size and type of intake screen if present. In each case, it was also determined whether or not the diversion could be adequately sampled for fish losses.

Pump intakes were located by probing with a three-quarter-inch by 12-foot aluminum pipe, with 6-inch graduations. This pipe was used to measure the depth of the intake and the distance between the intake and the river bank. The angle at which the intake pipe entered the water was estimated. Velocity of flow past the intake was measured with a Leitz current meter. Since the water was usually murky, information on the size and type of intake grids or screens was usually obtained from the owner or ranch foreman. This information applied only to the time that the intake was installed or last repaired, and therefore the condition of the screen at the time the survey was made was generally unknown. Data gathered on each pump were recorded on a "Unisort" edge-punched card to facilitate grouping and sample selection.

The Anderson-Cottonwood Irrigation District diversion at Redding was the only gravity flow diversion found along the upper Sacramento River: the remainder divert water by pumping.

A total of 23 diversions was sampled intermittently for fish losses during the 1953 irrigation season, with the greatest effort being expended during midseason. No diversion was found to be taking fingerling salmon or steelhead in serious quantities (Table 1).

In 1954, fyke nets were fished in nine selected diversions in the vicinity of Colusa, all with pumps from 14 to 50 inches in diameter, from late April through September. Fyke nets were also fished in other diversions for varying lengths of time (Table 2). Although some losses occurred during the entire irrigation season, particularly during the early part, the findings were essentially the same as in 1953, in that fish

TABLE 1

Diversions Sampled on the Sacramento River in 1953

Diversion	Location (mile and bank above Sacramento)	Number and size (diameter in inches) of pumps	Date	Hours of fyke netting	Number of juvenile salmon captured	Remarks
Anderson-Cottonwood Irrigation District	240.5 L	4-16	April 6-Aug. 20	134	136	All of the king salmon were captured during the period April 6-16, 1953. Combined catch of two nets.
Olive Percy Davis, et al.	78.8 R	1-24	July 27-Aug. 13	128	26	Pump broke down during night of July 27; time unknown.
Reclamation District No. 1004	112.1 L	2-30 1-50	June 3-18	94	1	
R. Pheiffer	155.7 R	1-2½	May 28-30	45		
V. G. Strain	150.8 R	1-12 1-16	June 16-17	26		
Provident Irrigation District	124.2 R	2-24 1-36 2-42	June 23-25	49		
Princeton-Codora Glenn Irrigation District	123.9 R	5-24	June 2-4	42		Combined catch of two nets.
Princeton-Codora Glenn Irrigation District	112.4 R	3-24	June 3-9	140		
Hollis Sartain	99.2 L	1-20	July 29-30	20		
Azro N. Lewis	95.6 L	1-12 1-20	Aug. 10-13	69		
Roger Wilbur	95.25 L	1-12 1-18	July 28-30	44		Not enough velocity to make a good set. Periodic water changing among ditches.
Roger Wilbur	87.4 R	1-10	July 27-28	8		Entire discharge sampled.
Wayne Hall	81.8 L	1-16	July 14-17	70		
Meridian Farms Water Company No. 1 and No. 2	80.0 L	1-10 1-20 1-24	July 15-17	48		
Olive Percy Davis, et al.	78.75 R	1-16 2-12	Aug. 10-13	64		
Robert Chesney	76.15 L	1-10	July 14-17	67		These pumps both discharge into the same basin; both pumps were operating during sampling.
J. H. Yates Estate	76.1 L	1-10				

TABLE 1

Diversions Sampled on the Sacramento River in 1953—Continued

Diversion	Location (mile and bank above Sacramento)	Number and size (diameter in inches) of pumps	Date	Hours of fyke netting	Number of juvenile salmon captured	Remarks
Meridian Farms Water Company No. 3	74.8 L	1-18	July 15-17	46		
Meridian Farms Water Company No. 4	71.1 L	1-24	Aug. 10-13	65		An estimated 60-70 dead salmonids (young and adults) observed in ditch August 10-12, 1953.
Faxon, Morton and P. Andreotti	69.2 R	1-10 2-16	July 27-30	34		
J. L. Browning	69.0 R	1-14 1-22	July 28	6		Only the 14-inch pump operated during sampling.
Newhall Land and Farming Company	67.5 L	1-12 2-24	July 14-17	64		
Natomas Central Mutual Water Company	16.0 L	1-24 2-32 2-38	Aug. 18-19	24		

losses at individual pumps were quite small. For example, the greatest seasonal loss encountered in 1954 consisted of 2,116 fingerling salmon and 110 yearling steelhead in the Olive Percy Davis diversion, with a 24-inch centrifugal pump. These are weighted figures, based on efficiency tests of the fyke nets fished in the canal behind the pumps, and represent the entire catch for the season. One pump was found to be operating unseasonally early, in March, 1954. This was a 20-inch centrifugal pump owned by the St. Patrick Home Ranch located between Princeton and Colusa. Fyke nets were fished in this diversion for eight days during the first half of March and over 1,200 fingerling salmon were captured. In addition, pieces of two adult salmon and one adult steelhead were recovered. This diversion was sampled again for three days during July, and no salmon or steelhead were taken.

There are indications that considerable damage could be done to the salmon and steelhead populations through losses of adults at pump intakes which do not have a trash grid or screen. A 24-inch centrifugal pump (Meridian Number 4) was sampled for three days in August, 1953. During this short period, 22 adult king salmon and 2 adult steelhead were captured in fyke nets. All were dead. In addition, between 60 and 70 dead adult salmon, which had either entered the canal before sampling began or were not captured in the fyke nets, were found floating in the ditch. Between the 1953 and 1954 irrigation seasons, a two-inch bar grill was placed over the pump intake by the irrigation company. In September, 1954, this diversion was examined again and no dead salmon were found in the canal.

TABLE 2

Diversions Sampled on the Sacramento River in 1954

Diversion	Location (mile and bank above Sacramento)	Number and size (diameter in inches) of pump	Date	Hours of fyke netting	Number of juvenile salmon captured	Fyke net efficiency (Percent)	Computed number of juvenile salmon captured, based on 100 percent fyke net efficiency and hours of fyke netting	Computed number of juvenile salmon captured, based on 100 percent fyke net efficiency and total possible hours of fyke netting during periods when salmon were captured
Olive Percy Davis, et al.	78.8 R	1-24	May 2-Sept. 11[1]	1,277	297	48.5	612	2,116
Meridian Farms Water Company No. 1 and No. 2	80.0 L	1-10 1-20 1-24	April 25-Sept. 18[2]	1,399	26	40.9	63	148
Reclamation District No. 1004	112.1 L	2-30 1-50	May 2-8	38	3			
Thousand Acre Ranch, H. W. Keller	106.0 R	1-14	April 25-May 29	290	4	Low velocity 95 percent of flow strained		
Charles W. Welch	103.7 R 103.8 R	1-16 1-14	April 25-May 8	115	2			
Nettie George and Ella Packer	102.8 R	2-12 1-20	May 9-29	167	1			
St. Patrick Home Ranch	101.1 R	1-20	Feb. 28-July 24	387	1,266	100.0 percent of flow strained		
Mayfair Packing Company	88.7 L	1-14	Oct. 3-9	8				
Howell Davis	86.2 R	1-18	July 4-10	44				
Wayne Hall	81.8 L	1-16	June 6-Sept. 25	1,242		66.0		
Olive Percy Davis, et al.	78.75 R	2-12 1-16	May 2-June 12	116	1			
J. H. Yates Estate	76.1 L	1-10	May 9-15	16				
Meridian Farms Water Company No. 3	74.8 L	1-18	April 25-Sept. 18	1,208	2	17.3		
Meridian Farms Water Company No. 4	71.1 L	1-24	April 25-May 22	209	2			
Hoffman, Beckley, Ritchie, Poundstone and Andreotti	70.4 R	1-16 1-20	April 18-Sept 4	811	3	70.0 percent of flow strained		
Faxon, Morton and P. Andreotti	69.2 R	2-16	June 13-Sept. 4	686		75.0 percent flow strained		
Newhall Land and Farming Company	67.5 L	1-12 2-24	April 25-May 8	156				
Tisdale Irrigation and Drainage Company	67.1 L	1-16 1-22	April 25-June 12	446		Medium velocity 50 percent of flow strained		
Tisdale Irrigation and Drainage Company	64.4 L	1-8 1-12	May 28-Sept. 18	113		100.0 percent of flow strained		
Sutter Mutual Water Company	63.75 L	2-48	May 23-Sept. 18	479	37			
W. A. Larner	60.4 L	1-14 1-16	May 16-Oct. 2	914	2	13.8		
Sacramento River Ranch	22.5 R	1-24	May 19-22	38	7			

[1] No estimate May 30-June 5.
[2] No estimate May 30-June 19 and June 27-September 18.

A summary of the individual diversions sampled with fyke nets during 1953 and 1954, together with the catches of all species, appears in the Appendix.

The only diversions in which fyke nets were fished along the upper Sacramento River during 1955 were the Meridian Farms Water Company Number 1 and Number 2 and the L. W. Seaver ditches. The pumping plant for the former is located near the City of Meridian and the one for the latter near Princeton. Nets were fished during the last week in March and the first week in April in the Meridian diversion and for one week only, in mid-March, in the Princeton diversion. Results, although meager, further substantiated findings from the 1954 work done on the Sacramento River in this same area.

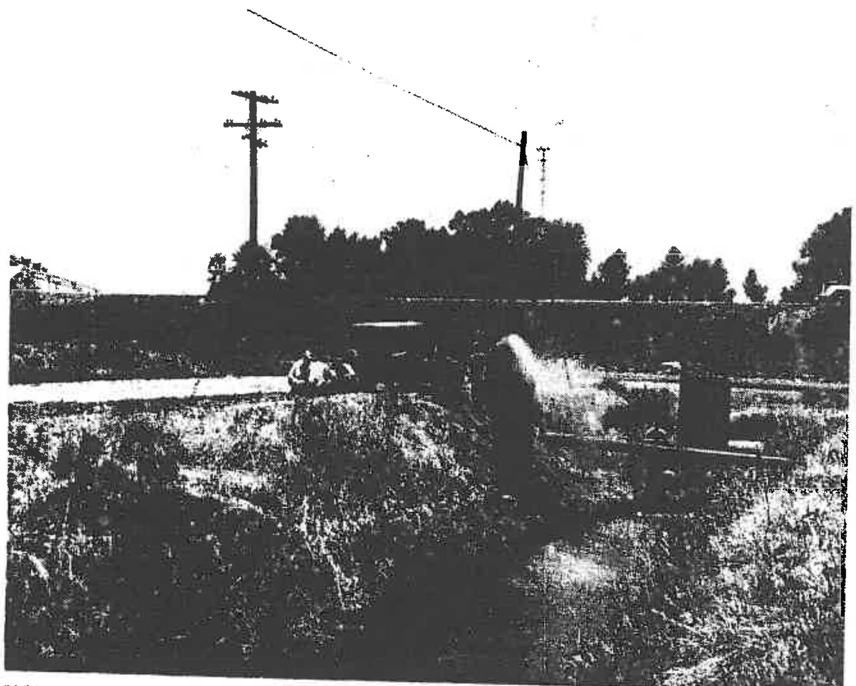

FIGURE 7. Method used to clean the fyke nets. The net has been suspended from a hoist on the front of the jeep and the debris is being washed away with a 1½-inch diameter portable pump. The men beside the jeep are sorting the catch. Meridian Farms Water Company diversions No. 1 and No. 2, Sacramento River, 1954. Photograph by Elton D. Bailey.

Previous Diversion Sampling

In several instances, previous diversion sampling by the Department of Fish and Game along the upper Sacramento River and some of its tributaries resulted in similar experiences, since the young fish had migrated downstream before the irrigation season got under way. For example, between May 1 and June 9, 1943, fyke nets were fished in the Feather River near Oroville and in the Sutter Butte Canal Company and Western Canal Company diversions, which take water from the Feather River near Oroville. Results of the study were summarized by the statement that, "the movement of salmon was evidently early,

and most of them had moved out of the river by the time the ditches began taking water. Results obtained cannot therefore be considered significant."

However, fyke nets were also fished in the Feather River near Gridley from January 23 to May 31, 1944, and from January 13 to May 28, 1955, and it was found in each instance that the heaviest downstream movement of juvenile king salmon occurred during March and April. The Western Canal Company ditch opened in mid-April in 1944 and took very few salmon that year. The Sutter Butte Canal Company diversion opened early in April during 1944, and moderate numbers of salmon were taken in this canal between mid-April and the end of May.

Nets were also fished in the Sacramento River near Chico between May 1 and June 9, 1943, and in the Glenn-Colusa Canal, which diverts water from the Sacramento River at a nearby point. Practically no young salmon were taken, and it was concluded, as in the case of the Feather River, that most of the fish had migrated past this area before the netting was started. However, nets operated between April 18 and August 20, 1929, in the same diversion took large numbers of game fish, including salmon and steelhead. Substantial numbers of salmon were being lost in this canal even in late June, 1929.

Conclusions (Sacramento River)

On the basis of the 1953 and 1954 Sacramento River studies, appreciable losses of salmon in irrigation diversions now occur at few places on the river itself above Meridian. Individually, most of the small irrigation diversions do not destroy many young salmon and steelhead. Collectively, however, they do take considerable numbers. The largest diversion, that of the Glenn-Colusa Irrigation District, was not sampled adequately, nor was the large Anderson-Cottonwood Irrigation District gravity diversion at Redding. In view of the migration time of fingerling salmon, which results in the bulk of the fish moving out of the upper river and reaching the delta by late March, and an irrigation season which does not get into full swing until late April and early May, the small losses encountered in the diversions are not surprising. However, sampling has shown that the unscreened diversions do take fish at times when the pumps are in operation while fish are migrating, even under near flood conditions. A change in agricultural practices, resulting in an earlier irrigation season, or the installation of year-round diversion canals for the transportation of water to other areas of the State, could prove disastrous to the Sacramento River salmon resources unless adequate screens were provided.

Although losses at pumping plants along the upper Sacramento River were found to be very small during the spring of 1953 and 1954, it should not be concluded that losses of the same low magnitude occur in diversions from tributary streams. On the contrary, losses are known to be considerable in diversions from many tributaries. One of the leading factors contributing to this situation is a generally later spawning (and later downstream migration of young) of fall-run salmon in tributaries than in the Sacramento River. This situation results from low flows in tributary streams early in the fall, which make the spawning beds inaccessible until the first rains of winter arrive. Another factor contributing to large losses in some tributary stream diversions is the removal of an increasing percentage of the stream flow as the season progresses, until the fish have no place to migrate except down the diversions.

SAN JOAQUIN RIVER

Salmon Migration

The annual migration of adult king salmon into the San Joaquin River system has consisted almost entirely of fall-run fish in recent years. Remnants of former large spring runs still persist in the Merced River, and to a much lesser degree in some of the other tributaries. Since the annihilation, by 1949, of salmon stocks which once spawned in the upper San Joaquin River, as a result of the lack of water releases from Friant Dam, the once important San Joaquin has served only as a passageway for salmon destined to spawn on riffles of tributary streams, including the Merced, Tuolumne, Stanislaus, Mokelumne, and Cosumnes Rivers.

The former San Joaquin River spring run, which included 56,000 salmon in 1945 and was valued at almost one million dollars annually, migrated past the mouth of the Merced between the middle of April and the middle of June, and usually peaked there in the first half of May. At Mendota, some 60 miles farther upstream, the adult run peaked during the early part of June. Spawning then took place in September and

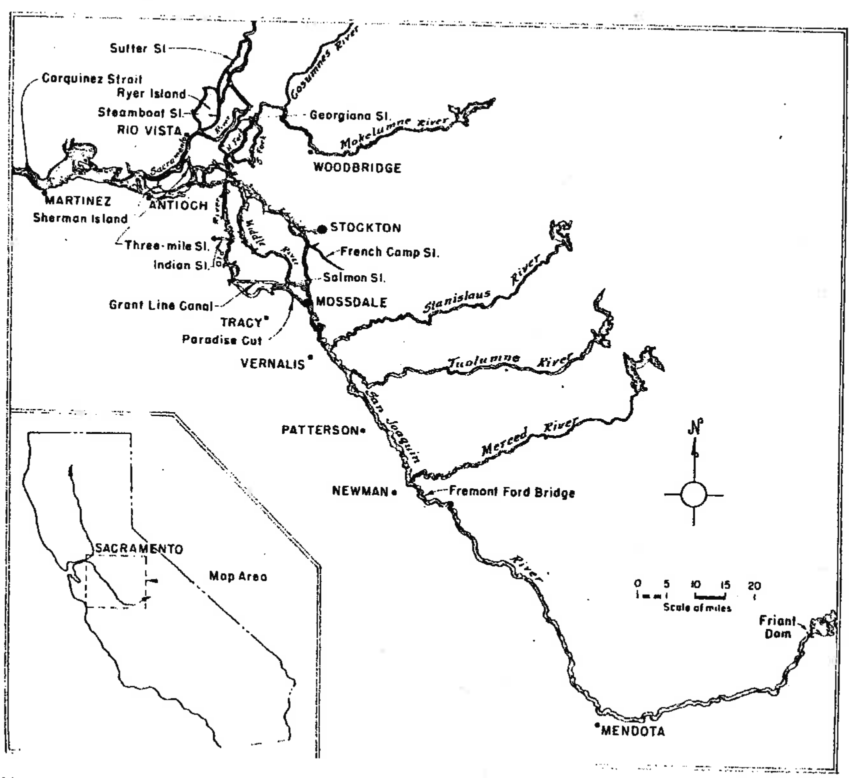

FIGURE 8. Map of the San Joaquin River system and the Sacramento-San Joaquin River Delta, showing the areas where irrigation diversions were sampled

early October in the San Joaquin River near Friant. In 1948 the Department of Fish and Game trapped 1,915 adult king salmon and hauled them to a canal through which they bypassed a dry section of the San Joaquin and reached the Friant Dam area safely. This was the last of this spring run.

The present fall run usually occurs a few weeks later than the Sacrament River fall run. There is also considerable variation in the time when these fish enter the tributaries. The Cosumnes and Merced Rivers have notoriously late runs, perhaps due in most years to low early flows, so that sometimes fish do not spawn in them until the middle of November. However, in the other tributaries the runs usually start in early October and continue through the middle of December, with a peak being reached some time in November.

The seaward migration of juvenile salmon in the San Joaquin River system occurs during the period of major seasonal runoff, as it does in the Sacramento. This was noted especially in studies made in 1940, prior to the storage of water at Friant Dam. However, while the storage of water behind Shasta Dam has had very little measurable effect upon the time pattern of juvenile salmon migrations in the Sacramento River, the storage of water at Friant Dam has brought about a considerable change in San Joaquin River fish migrations.

Fyke netting by the Department of Fish and Game in the San Joaquin River near Mendota between 1944 and 1949 showed that the majority of the fish then passed Mendota between late January and early June. In 1944 the migration of juvenile salmon was heavy at Mendota from January 27 through March and reached a peak in mid-February. Farther downstream, fyke netting at Mossdale in 1939 and 1940 demonstrated a measurable seaward movement of fingerling salmon between January and mid-June, with the greatest numbers descending during February and March. The highest percentage of the total number of migrants taken during any one month was 61 percent, during February, 1940.

The elimination of San Joaquin River flood flows as a result of water storage at Friant Dam considerably altered the juvenile salmon migration pattern. In 1948, at Mendota, there was a fairly steady downstream migration between February and June, but the peak was not reached until April. In 1949 the seaward migration was again measurable at Mendota between February and June, with peaks in early March and again in mid-May.

Juvenile salmon passing Mendota, at least in the decade prior to 1949, were for all practical purposes the progeny of spring-run adults only, since very few fall-run fish spawned in the upper San Joaquin. In 1948 and 1949 the last of the downstream migrants from the upper San Joaquin reached Mendota, only to be destroyed in irrigation diversions nearby. Only enough water was released from Friant Dam to fill the needs of agriculture, thus leaving a dry streambed, except for return irrigation water, from a few miles below Mendota to the mouth of the Merced, a distance of some 60 miles.

Fyke netting in the Delta in 1948 and 1949, then, for the first time did not include catches of fingerlings from the upper San Joaquin. All fingerlings were from spawning beds of tributary streams and were primarily the progeny of fall-run adults. This condition has existed until the present time, i.e., the tributary streams from the Merced River to the Cosumnes now support the entire San Joaquin River salmon runs.

In 1948 and 1949 the San Joaquin River system seaward migrants did not reach the Delta near Stockton until the first week in April. This was six weeks after those from the Sacramento River drainage began entering the Delta waters near Hood. During 1949, salmon fingerlings moved seaward through the lower San Joaquin and into the Delta while the stream flow was actually receding, and it continued to recede during the migration period. In 1955 the peak of the downstream migration near Newman occurred between mid-March and mid-April. Thus, with the elimination of the early spawning spring run which formerly used the gravels above Mendota, and the storage of water at Friant, the juvenile salmon migration time pattern in the San Joaquin has changed considerably. During years of normal runoff, it formerly peaked near Stockton in February and it now peaks there around the last of March.

Irrigation Season

Records for the 10-year period (1946-55) show the irrigation season along the San Joaquin River between Stockton and the mouth of the Merced River to be principally between March and October, with some water diverted in February and November (Figure 9). Upstream, at Mendota, water is usually diverted during all months of the year. The monthly diversion of water in percentage of the seasonal total indicates that—between Stockton and the Merced River—5.8 percent is diverted in March, 14 percent in April, and 14 percent in May. About 67 percent is diverted from May through August, inclusive. On an average, about

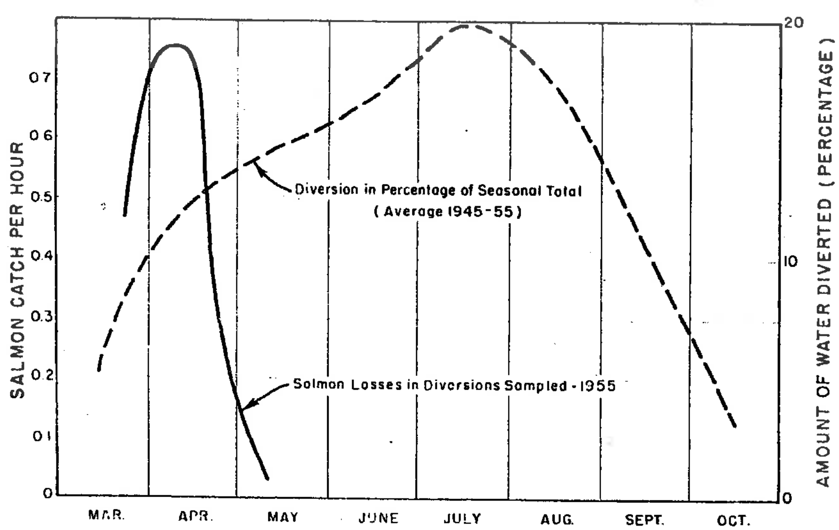

FIGURE 9. Comparison between times of San Joaquin River king salmon fingerling losses in irrigation diversions and the diversion of water for irrigation. Salmon losses were determined by fyke netting in irrigation diversions from the San Joaquin River between Patterson and Stockton (Old River). The average diversion of irrigation water in percentage of the seasonal total includes data for the entire river between Stockton and Newman (Fremont Ford.)

127,000 acre-feet of water are diverted annually in this river section, which means that during the eight principal months of the irrigation season an average of approximately 261 cubic feet of water per second leaves the river through the many diversions.

Fingerling Salmon Migration and the Irrigation Season

In comparison with Sacramento River diversions, those along the San Joaquin divert a much greater percentage of the river flow during the time when salmon fingerlings are migrating. For example, in 1955, Patterson Water Company diverted 17 percent of the entire flow of the San Joaquin River at its diversion intake during March, and by May was taking 20 percent of the flow. Farther downstream, at the Banta-Carbona Irrigation District intake, 4 percent of the river flow was diverted in March and 17 percent in April. A comparison between time of annual seaward migration of juvenile salmon, as determined by fyke net catches in irrigation diversions, and time of diversion of the combined volume of water diverted from the San Joaquin River in 1955 by all pumps between Stockton and the Merced River, shows that a much greater overall percentage of the seasonal irrigation water was pumped during the time fingerling salmon were migrating than on the upper Sacramento (Figure 9). Under these conditions, considerable fish losses were expected in the diversions sampled, and that is what happened during the 1955 irrigation season. The fish losses along the San Joaquin result not only because the irrigation season coincides with the juvenile salmon migration, but also because a large percentage of the entire San Joaquin flow is diverted early in the irrigation season, during the salmon migration period. In 1955 all pumps between Stockton and Patterson diverted about 20 percent of the entire San Joaquin flow in March and 40 percent in April.

Diversions Sampled and Fish Losses

In 1955 there were 113 separate diversions, utilizing 159 pumps, along the San Joaquin River between Stockton and the mouth of the Merced River. These diversions do not include those from French Camp Slough and Old River. The pumps varied in size from 2 to 36 inches in diameter, with about 85 percent being from 6 to 24 inches in diameter. As on the Sacramento River, the majority of the diversions are headed by single and double pump installations, with a few larger pumping plants which supply water to vast irrigation districts. The four largest water users include the Banta-Carbona Irrigation District, which utilizes 10 pumps ranging in size from 10 to 36 inches in diameter; West Stanislaus Irrigation District, with eight pumps from 12 to 26 inches (six of which are 26-inch pumps); Patterson Water Company, with seven pumps from 14 to 36 inches; and El Solyo Water Company, with a battery of four pumps from 10 to 18 inches in diameter.

Rather than to spend a season surveying the more than 100 diversions along the upper San Joaquin, as had been done in 1953 on the Sacramento, it was decided to forego this work on the San Joaquin and sample several of the larger typical pumping stations thoroughly during the entire 1955 season. This was done for the sake of expediency and to obtain a general picture of fish losses sooner. Previous work at several diversions in this area furnished some information and made this approach possible.

TABLE 3

Diversions Sampled on the San Joaquin River in 1955

Diversion	Location (mile and bank above mouth)	Number and size (diameter in inches) of pump	Date	Hours of fyke netting	Number of juvenile salmon captured	Fyke net efficiency (percent)	Computed number of juvenile salmon captured, based on 100 percent fyke net efficiency	Computed number of juvenile salmon captured, based on 100 percent fyke net efficiency and total possible hours of fyke netting during periods when salmon were captured
Banta-Carbona Irrigation District	67.5 L	2-10 2-16 2-20 3-24 1-36	Mar. 20-May 28[1]	504	386	6.4	6,024	19,748
El Solyo Water Company	82.0 L	1-10 3-18	Mar. 20-June 11[2]	428	105	4.7	2,234	9,494
Patterson Water Company	104.4 L	1-14 2-18 3-30 1-36	Mar. 20-May 28[3]	536	21	2.4	875	2,157

[1] No estimate May 15-28.
[2] No estimate April 24-June 11.
[3] No estimate March 20-26, April 17-23, and May 8-28.

In the spring of 1955, then, practically all of the diversion sampling was done on the San Joaquin River and in the Sacramento-San Joaquin River Delta. Pump diversions in which nets were fished along the San Joaquin included the Banta-Carbona Irrigation District and the El Solyo and Patterson Water Companies, located along a 43-mile section of the San Joaquin River between Stockton and Patterson. The large West Stanislaus Irrigation District diversion above Stockton was not sampled, but previous studies had shown this pumping plant to be an important salmon destroyer. All of the diversions sampled in 1955 on the San Joaquin River appear to be destroying more fingerling salmon than any of those sampled during the 1953, 1954, or 1955 seasons along the upper Sacramento River (Table 3). Of those diversions on the San Joaquin which were successfully studied, the Banta-Carbona Irrigation District pumping plant appears to be one of the greatest destroyers of young salmon. This irrigation district includes 17,000 acres of land. The diversion point is located on the west bank of the San Joaquin some 10 miles east of Tracy. The water flows by gravity about one mile to the headworks, where there are 10 pumps ranging in size from 10 to 36 inches in diameter. The average monthly flow through these pumps during April, May, and June for the five-year period 1948 through 1952 was slightly over 125 cubic feet per second. Juvenile salmon migrating down the San Joaquin River past the intake originate in the Merced, Tuolumne, and Stanislaus Rivers, all of which flow into the

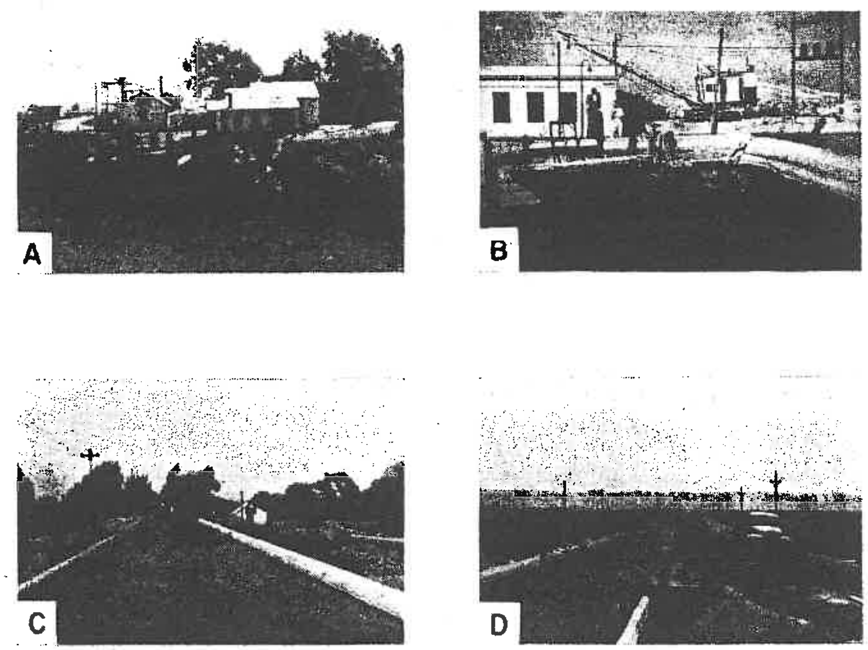

FIGURE 10. Two of the large irrigation diversions sampled along the San Joaquin River in 1955. A, Patterson Water Company pumping plant; B, Banta-Carbona Irrigation District pumping plant No. 1; C, Patterson Water Company canal, view toward the pumping plant; D, Banta-Carbona Irrigation District canal near pumping plant No. 2. *Photographs A, C, and D by John E. Riggs; and B, by William F. Van Woert.*

San Joaquin farther upstream. The studies showed that close to 20,000 juvenile salmon were destroyed in this one diversion during a two-month period between the middle of March and the middle of May, 1955.

During a one-month period of testing, between the middle of March and the middle of April, 1955, the El Solyo Water Company diversion, situated on the west bank of the San Joaquin River near Vernalis, took over 9,000 fingerling salmon. This diversion, which at the headworks includes four pumps ranging in size from 10 to 18 inches, has a normal average pumping rate of about 35 cubic feet per second during the salmon migration period. The intake is located above the mouth of the Stanislaus River, so that downstream migrants at that point originate in the Merced and Tuolumne rivers only. Percentage-wise, this diversion may be a greater destroyer of young salmon than the Banta-Carbona, since it draws from the migrants of one less river.

The same reasoning might also be applied to the results of studies made at the Patterson Water Company diversion. This company diverts water from the west bank of the San Joaquin River near Patterson, to provide for an irrigation district which includes 15,000 acres of land. At the headworks there are seven pumps, ranging in size from 14 to 36 inches in diameter. During the salmon migration period, flow through the pumps averages close to 110 cubic feet per second. Studies showed that between the middle of March and the early part of May more than 2,000 fingerling salmon were lost in this canal. However, although the number of fish destroyed was small, these fish were important, for this diversion draws on migrants only from the Merced River, and the run of adult salmon into the Merced the previous spring and fall was probably less than 1,000 fish.

A summary of the individual diversions sampled with fyke nets during 1955, along with catches of all species, appears in the Appendix.

Conclusions (San Joaquin River)

The 1955 studies on the San Joaquin River show that all of the large diversions sampled between Stockton and Patterson are destroying appreciable numbers of salmon fry. This is not surprising, since between 20 and 40 percent of the entire river flow is pumped into irrigation canals during the period when salmon are migrating downstream in this river section.

SACRAMENTO-SAN JOAQUIN RIVER DELTA

Originally it had not been planned to sample diversions in the Sacramento-San Joaquin River Delta as a part of this study. However, the need to obtain more data on fish losses in this area, particularly in some of the pump diversions with fish screens of questionable effectiveness, and in the large siphon diversions, had existed for some time. Accordingly, as time permitted, fyke nets were fished in several Delta diversions during March and April, 1955. Most of the San Joaquin River diversions ceased taking fingerling salmon early in May of 1955, and all work was shifted from the San Joaquin River above Stockton into the Delta.

Salmon Migration Time

Upon reaching the Delta, Sacramento River king salmon fingerlings migrate down the main stem of the river and the principal diverging channels, Sutter, Steamboat, and Georgiana sloughs, more or less in proportion to their respective flows (Erkkila et al., 1950). Studies in the Delta in 1948 and 1949 showed that although most Sacramento River migrants moved directly downstream, considerable numbers also traveled by way of Georgiana Slough, Three Mile Slough, and Sherman Lake.

In 1949 the bulk of the Sacramento River juvenile salmon had passed through the Delta by ~~the end of March, but some fish continued to enter~~ the Delta until mid-June.

Fingerling salmon entering the Delta from the San Joaquin River in 1949 traveled principally along Middle River to Salmon Slough and Grant Line Slough, then down Old River. They did not enter the Delta until early April, ~~and then continued to do so through the latter part~~ of June. The seaward movement of these fish from the Delta was measurable through July.

At Martinez, located at the lower end of the Delta on Carquinez Strait, fingerling salmon migration records are available for 1939 and 1940 (Hatton and Clark, 1942). During these two years the majority of the fish migrated seaward between the last of February and the middle of May, with more than 80 percent of them descending during March.

Diversions Sampled and Fish Losses

In 1955 the East Contra Costa Irrigation District and the United States Bureau of Reclamation's Contra Costa Canal, both of which divert water from the Delta near the City of Antioch, were sampled for fish losses. Two large siphons on Ryer Island, which is situated on the Sacramento River side of the Delta just upstream from Rio Vista, were also sampled. The siphons included one operated by Reclamation District 501 and another by the Passaglia Brothers. Woodbridge Irrigation District's gravity flow diversion on the Mokelumne River was also sampled early in the season, but work was discontinued because of low water velocities in the canal, which rendered the sampling gear ineffective. All of the sampled diversions were found to be taking young salmon (Table 4). However, with the exception of the East Contra Costa Irrigation District diversion, it was not possible to determine fyke net efficiencies so as to compute a total loss for any test period, because of scarcity of live fish for marking.

The East Contra Costa Irrigation District diversion was the only diversion in the Delta on which studies were carried out over a significant period of time. This diversion is located 36½ miles upstream from the mouth of the San Joaquin River on Indian Slough. At the headworks of this diversion, located at the end of a 1½-mile-long canal leading from Indian Slough, there are six pumps, ranging in size from 18 to 30 inches in diameter. The average monthly flow through these pumps during April, May, and June for the five-year period 1948 through 1952 was slightly over 50 cubic feet per second. The studies indicated that over 6,000 fingerling salmon were destroyed between early April and mid-June in this canal.

TABLE 4

Diversions Sampled in the Sacramento-San Joaquin River Delta in 1955

Diversion	Location	Type, number, and size (diameter in inches) of diversion	Date	Hours of fyke netting	Number of juvenile salmon captured	Fyke net efficiency (percent)	Computed number of juvenile salmon captured, based on 100 percent fyke net efficiency	Computed number of juvenile salmon captured, based on 100 percent fyke net efficiency and total possible hours of fyke netting during periods when salmon were captured
East Contra Costa Irrigation District	San Joaquin River near Antioch	Pump 2-18, 2-24, 2-30	Apr. 3-June 18[1]	610	234	10.5	2,228	6,148
United States Bureau of Reclamation, Contra Costa Canal	San Joaquin River near Antioch	Pump 1-30, 2-42	May 29-June 18	113	20			
Reclamation District 501	Sacramento River at Ryer Island	Siphon 1-30	May 29-June 18	183	48			
Passaglia Brothers	Sacramento River at Ryer Island	Siphon 1-20	May 29-June 18	162	19			
Woodbridge Irrigation District	Mokelumne River at Woodbridge	Gravity	Mar. 27-May 7	326	3			

[1] No estimate May 15-21.

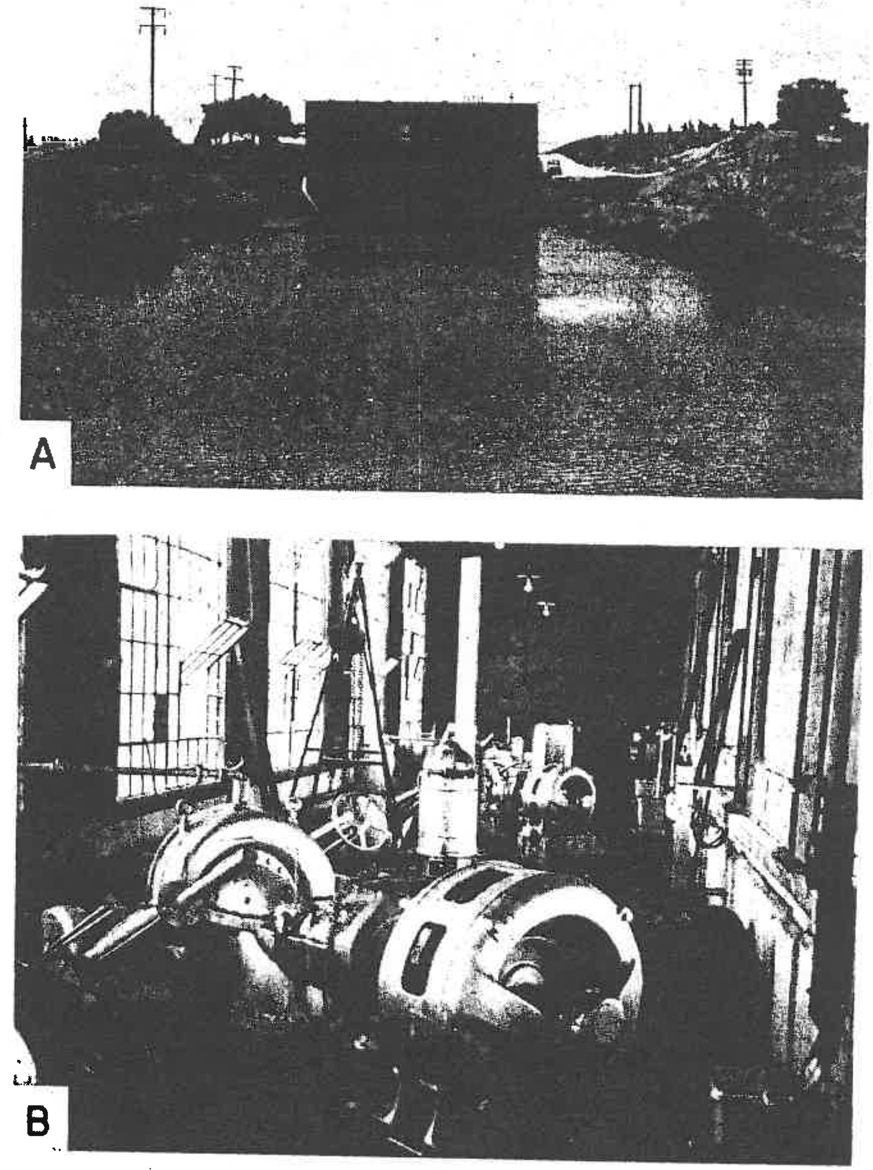

FIGURE 11. Two pumping plants in the Sacramento-San Joaquin River Delta at which fish losses were studied, 1955. A, The United States Bureau of Reclamation's Contra Costa Canal pumping plant; B, interior view of the East Contra Costa Irrigation District pumping plant. *Photographs by John E. Riggs.*

A summary of the individual diversions in the Delta sampled with fyke nets during 1955, along with the catches of all species, appears in the Appendix.

Conclusions (Sacramento-San Joaquin Delta)

Although the test periods were short, it was demonstrated that fish screens are needed at the East Contra Costa and Contra Costa canals, since considerable losses occur in these diversions. Further, the large siphons in the Delta are also destroying salmonids and other kinds of fishes. Additional study should be directed toward determining the extent of the siphon problems in the Delta, and the fish losses at the Woodbridge Irrigation District diversion.

SALMON MORTALITY

Since an efficient and economical fish screen for pump intakes has not been developed, the possibility of installing screens in canals to save juvenile salmon and steelhead after they have passed through the pumps was considered. Screens placed in canals below the pumps would be practical only if a large percentage of the young fish passed through the pumps alive and uninjured.

Studies showed that injuries received by fingerling salmon in passing through irrigation pumps in the Central Valley were similar to those listed by Schoeneman and Junge (1954) for downstream migrant salmon at dams on the Elwha River in Washington. Injuries which they commonly observed included: bulging or missing eyes, loss of scales, torn fins, ruptured abdomen, and "bisection." Although the causes of observed fish injuries were not determined in the present study, the injuries probably resulted in the ways suggested by Schoeneman and Junge, i.e., from pressure changes and mechanical causes, or a combination of the two. It was also found in the present study that some of the observed injuries, including missing eyes, loss of scales, torn fins, and ruptured abdomens, could result from use of a certain type of net in a high velocity discharge.

Since the causes of fish injuries were not definitely determined, and since in many cases pump injuries could not be distinguished from fyke net injuries, only the condition of salmon trapped in pump diversions at which fishing conditions were close to optimum for the available gear is covered[1] in this report. The number of deaths resulting from latent injuries received in passing through the pumps was not determined, since live fish were returned to the river immediately or used to determine fyke net efficiencies.

Riffle fyke nets have been used successfully to live trap fingerling king salmon by Hallock, Warner, and Fry (1952) in velocities of 1 to $1\frac{1}{2}$ feet per second. On the Sacramento River at the St. Patrick Home Ranch, where two of these nets were used to sample the discharge from an 18-inch centrifugal pump, 87.4 percent of the juvenile salmon taken were alive and apparently uninjured (Table 5). At the other Sacramento River diversions sampled, either velocities in the canals were unsuitable for efficient live trapping, or the numbers of salmon captured were too small to permit a reliable estimate of mortality.

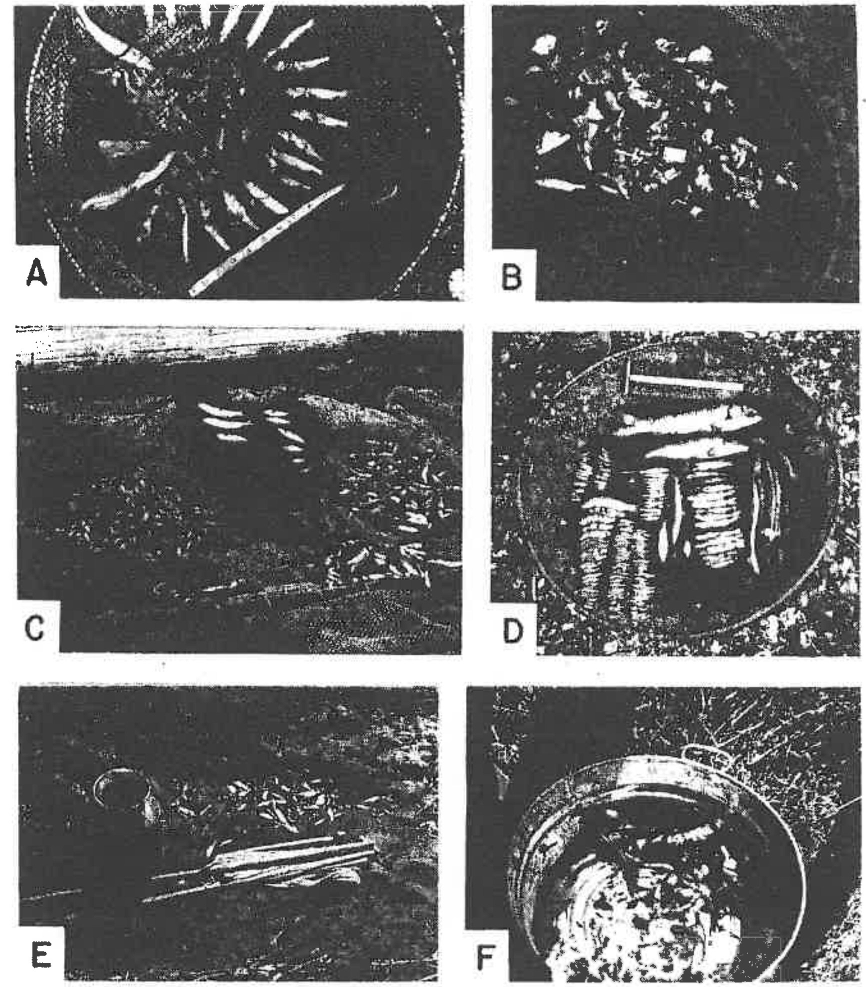

FIGURE 12. Typical daily fyke net catches (except E), showing the scarcity of salmonids, and the differences between fish which have passed, respectively, through centrifugal and screw-type pumps. A and F, Meridian Farms Water Company No. 1 and No. 2, showing catfish, lampreys, sunfish, and salmon (A, right portion of circle); these fish passed through large centrifugal pumps; note whole fish up to 7 and 8 inches in length; B, Faxon, Morton, and P. Andreotti irrigation diversion, showing fish after passing through a screw-type pump; most of the fish have been cut into small pieces; C, D, and E, Olive Percy Davis et al irrigation diversion, showing catches of lampreys, carp, sunfish and some salmon; the fish up to 18 inches in length were passed "whole" through a 24-inch diameter centrifugal pump; after this canal was drained at the end of the irrigation season, all that remained were small cyprinids, sunfish, and catfish (E). *Photographs A, B, D, and F, by William F. Van Woert; and C, by Dalan R. Drane.*

Two rectangular fyke nets with aluminum perforated plate live boxes attached were used for diversion sampling along the San Joaquin River and in the Delta. Limited use of this type of net at a Sacramento River diversion had indicated that the live boxes would provide more reliable information on pump mortality.

TABLE 5

Survival of Juvenile Salmon Passing Through Irrigation Pumps

Water user	Salmon captured				
	Number			Percentage	
	Live	Dead	Total	Live	Dead
Sacramento River					
St. Patrick Home Ranch	898	129	1,027	87.4	12.6
San Joaquin River					
El Solyo Water Company	32	11	43	74.4	25.6
Banta-Carbona Irrigation District	36	136	172	20.9	79.1
Sacramento-San Joaquin River Delta					
Reclamation District No. 501	14	2	16	87.5	12.5
Passaglia Brothers	16	2	18	88.9	11.1
Contra Costa Canal (Bureau of Reclamation	18	1	19	94.7	5.3

As previously stated, the El Soyo Water Company and Banta-Carbona Irrigation District diversions on the San Joaquin River and the United States Bureau of Reclamation's Contra Costa Canal in the Delta were large, multiple pump plants. With a fyke net set in the canal near the discharge outlets of several pumps, it was often impossible to tell through which pump the fish had passed. Therefore, no information is available on the mortality caused by individual pumps.

Reclamation District 501 and Passaglia Brothers diversions in the Delta were both siphons, through which fingerling salmon should be able to pass without injury. The small numbers of dead salmon observed at these locations probably resulted from net injuries.

From the limited data obtained, it is evident that many juvenile salmon pass through some pumps alive (Table 5). In general, there appeared to be a tendency for fish to pass through some of the older centrifugal pumps alive and apparently uninjured, while passage through some of the newer screw-type pumps usually resulted in death and often "bisection."

BUTTE CREEK

King Salmon Migration

Butte Creek presents a rather unique problem to those managing its salmon populations, since it is theoretically possible for Feather River salmon, both young and adults, to use the lower end of Butte Creek as a migration route to and from the Sacramento River. This could be accomplished through the unscreened Western Canal Company diversion, leading from the Feather River near Oroville to Butte Creek near Durham. To further complicate the picture, adult salmon may also enter Butte Creek from the Sacramento River via Sacramento Slough and the Sutter Bypass without passing through the flap gates at the mouth of Butte Creek, which lead through a levee to the Sacramento River at Ward's Landing. Fingerling salmon are also free to use the latter route but, of course, they would be moving in the opposite direc-

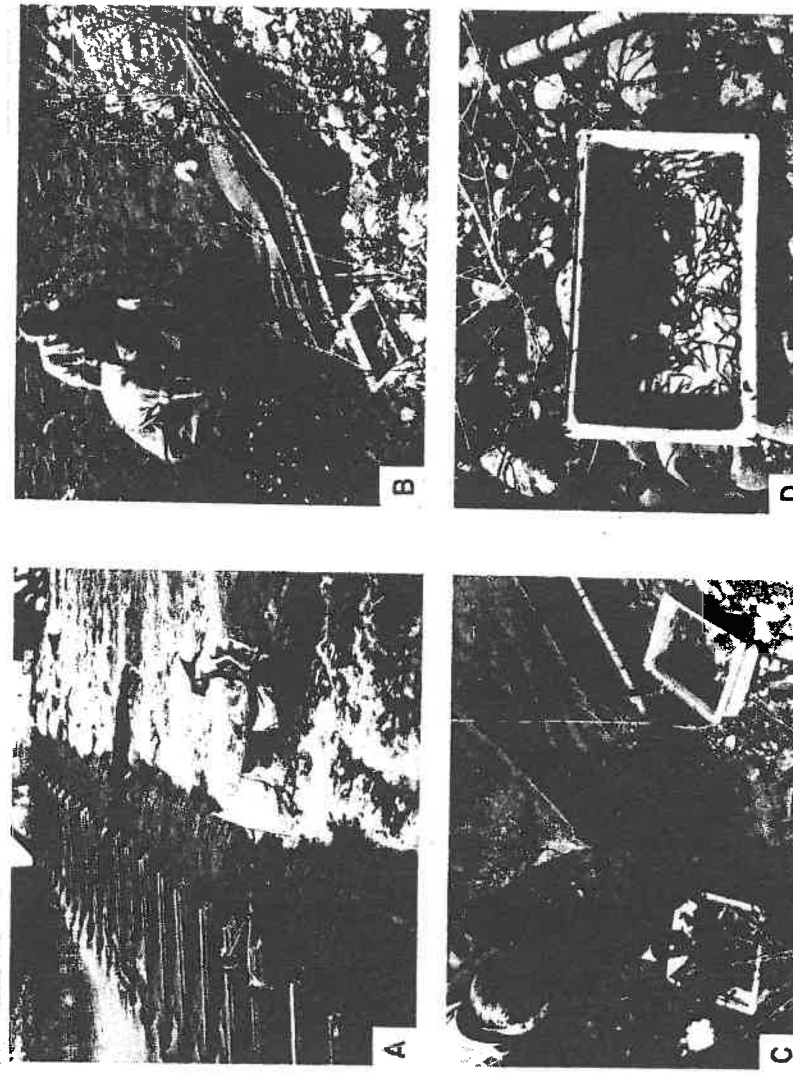

FIGURE 13. Determining the juvenile salmon migration time in Butte Creek. A, setting a fyke net below the apron of the Western Canal Company dam; this dam is a demountable structure, and the flashboards are not installed; B, examining the fyke net on shore, before removing the catch; C, sorting out the trash and examining captured salmon for marked fish; D, typical daily fyke net catch of salmon during the migration period. *Photographs by John E. Riggs.*

tion. There is evidence that salmon use these so-called secondary routes; however, the numbers involved are unknown.

Butte Creek supports an early spring run of adult king salmon, the bulk of which spawn in the 10-mile section below the Centerville Powerhouse in late September and early October. The remnants of a late fall run still persists, and occasionally considerable numbers of fish are able to find their way through the maze of commercial gun club and irrigation diversions from the lower stream to reach the spawning beds. Fall-run salmon were observed spawning in Butte Creek as far downstream as the Western Canal Company dam in 1956.

In March, April, and May, 1956, fyke nets were fished in Butte Creek below Gorrill Dam and the Western Canal Company dam, to determine the time of seaward salmon migration. However, only one juvenile salmon was captured during the entire three months, so it was apparent that there was either a poor hatch or the migration had taken place prior to the netting. Since flood conditions prevailed prior to the netting operation, it is probable that the scarcity of fish was due to both a poor hatch and an early but complete migration of fish from the eggs that did hatch.

In 1957, fyke netting was begun during December to determine the time of downstream migration. Fingerling salmon were found moving seaward in measurable quantities during the latter part of December, and the migration continued through the early part of March. The bulk of the fish moved out of the stream, or at least out of the area above the Western Canal Company diversion dam, in February.

Irrigation Season

The normal irrigation season on Butte Creek coincides with that of the Sacramento River above Sacramento, i.e., it does not get into full swing until late April and continues through September. However, some water is usually diverted from the lower section of Butte Creek through December by commercial gun clubs.

Diversions Sampled and Fish Losses

There are eight large unscreened irrigation diversions from Butte Creek, along a 25-mile section near Chico. Water enters six of them by gravity and is pumped into the other two. Lower Butte Creek also supports a host of diversions which supply water to commercial gun clubs and agricultural land. During part of each summer, water in the lower end of Butte Creek is supplemented and eventually replaced entirely by Feather River water, which is transported via the Western Canal Company ditch. The last of the Butte Creek water is usually diverted above the Western Canal Company dam.

In the spring of 1956, even though no juvenile salmon were being captured in fyke nets fished in Butte Creek, during April nets were also operated in irrigation diversions, including those of the Phelan-Parrott Irrigation System (often referred to as Parrott-Phelan) and Durham Mutual Water Company, Ltd., to further verify the scarcity of fingerlings. No salmon were captured. Since no fingerlings to study losses in the diversions were available, work was shifted toward the determination of the extent of adult spring-run salmon losses in these same diversions. It was soon found that many of these fish strayed into the unscreened gravity-flow diversions and were unable to find their way back to the stream. For example, on April 25 about 40 adult salmon were visible at one time in the Western Canal Company diversion. These fish had passed from the creek into the canal through the headgates and were then concentrated in the canal near the headgates in an attempt to re-enter the creek. Reduction of the velocity of water entering the canal failed to induce any salmon to return to the creek. Later, observations revealed that these fish did not re-enter the creek and perished in the canal.

In May, 1956, adult salmon were again observed in the Western Canal Company diversion, as well as in the diversions leading from Adam's Dam and the Phelan-Parrott Dam. Adult salmon were also reported by sportsmen to be present in the Durham-Mutual Water Company canal.

Adult salmon were also observed in the Western Canal Company diversion during May, 1957, but estimates of the numbers involved were not obtained. Simple trash grids installed at irrigation diversion headworks would save many adult salmon each spring in Butte Creek.

In 1957, two diversions, Phelan-Parrott and Durham Mutual, were found to be operating unseasonally early. Each diverted water off and on during January and February, then shut down again. Fyke nets were fished in the canals during these periods, and again it was demonstrated that losses of salmon occur in unscreened diversions if water is being diverted when the salmon are migrating (Table 6).

In only one instance were sufficient tests conducted to determine the percentage of the fish migrating down Butte Creek taken by a particular diversion. These studies were made at the Phelan-Parrott Irrigation System's gravity flow diversion during a five-day period in the middle of January, 1957. As previously stated, this diversion was operated during the early part of the juvenile salmon migration, prior to the normal irrigation season. During the five days of testing, close to one-sixth of the juvenile salmon moving seaward past the intake were drawn into the canal, with only about 20 cubic feet of water per second being diverted.

Results of the limited tests on Butte Creek were not surprising in view of the findings of other workers. Wales and Coots (1955) found that salmon losses were approximately proportionate to the amount of water being diverted into a specially constructed test diversion from Fall Creek, Siskiyou County, California. For example, when 10 percent of the water was diverted, 10 percent of the migrating fish entered the gravity flow diversion. Studies by the Department of Fish and Game in the Los Molinos Mutual Water Company's lower diversion from Mill Creek during 1951 revealed that between February 20 and March 27, with a water flow into the ditch of between 16 and 35 cubic feet per second, about 10,000 fingerling salmon or one-seventh of the total downstream migrants which passed the intake were destroyed. At this same site, during a three-day period in the early part of April, 1951, when between 40 and 65 cubic feet of water per second was being diverted, close to one-fourth of the downstream migrants were drawn into the diversion.

A summary of the individual diversions sampled with fyke nets during 1957, along with the catches of all species, appears in the appendix.

TABLE 6

Diversions Sampled on Butte Creek, 1956 and 1957

Diversion	Location	Type of diversion	Date	Hours of fyke netting	Number of juvenile salmon captured	Fyke net efficiency (percent)	Computed number of juvenile salmon captured, based on 100 percent fyke net efficiency	Computed number of juvenile salmon captured, based on 100 percent fyke net efficiency and total possible hours of fyke netting during periods when salmon were captured
Phelan-Parrott Irrigation System*	Butte Creek near Chico	Gravity	Apr. 10-12, 1956 May 2-4, 1956	120				
Durham-Mutual Water Company, Ltd.; R. Bank	Butte Creek near Chico	Gravity	Apr. 10-12, 1956	48				
Phelan-Parrott Irrigation System*	Butte Creek near Chico	Gravity	Jan. 6-Feb. 9, 1957	256	118	15.2	776	2,545
Durham-Mutual Water Company, Ltd.; R. Bank	Butte Creek near Chico	Gravity	Feb. 3-Feb. 23, 1957	192	205	18.0	1,139	2,995

* Often referred to as Parrott-Phelan.

Conclusions (Butte Creek)

One might conclude from results of the 1956 and 1957 studies on Butte Creek that losses of fingerling salmon are so small that fish screens would be hard to justify economically under present agricultural practices. However, findings of the 1956 and 1957 work conflict with the results of tests made by the Department of Fish and Game at many of the same diversions in 1955. Whereas no fingerlings were present in Butte Creek in the spring of 1956 and none after mid-March in 1957, they were recovered in fair numbers in six of the eight diversions during the middle of April in 1955.

Variance in the test results points up the need for further work on this stream before a screening program for juvenile salmonids is adopted or abandoned. The loss of adult salmon in the diversions was amply demonstrated in 1956 and 1957, and the need for screens to protect them is obvious.

SUMMARY

There are more than 900 irrigation, industrial, and municipal water supply diversions above the Sacramento-San Joaquin River Delta from stream sections utilized by salmon, steelhead, and other anadromous fishes as migration routes to and from the sea. Most of these diversions are for irrigation. Practically all irrigation water diverted from the Sacramento and San Joaquin rivers is pumped.

In 1953 the California Department of Fish and Game initiated a survey of the Central Valley diversions and of the over-all salmon and steelhead losses occurring in them. Specific fish loss data were also sought for particular diversions under consideration for screening in the near future. The study was especially aimed at determining king salmon losses.

The method of diversion sampling consisted of fishing fyke nets of various types in the canals and releasing marked fish to determine net efficiencies.

Adult king salmon migrate into the upper Sacramento River system during all months of the year. There are three main runs: winter, spring, and fall.

There is a measurable seaward migration of fingerling salmon in the Sacramento River near Balls Ferry between early October and the latter part of May in most years. However, the majority of the fish migrate out of the upper river between early December and late April. In the upper river, during periods of normal flow, fingerlings migrate downstream fairly uniformly across the river and principally at depths varying from the surface to four feet. They move in greatest numbers between two and four feet. In the lower Sacramento River near Hood, the seaward migration occurs between mid-December and early June, with maximum numbers migrating in February and March.

The irrigation season along the Sacramento River between Sacramento and Redding extends from March to October. However, only 0.5 percent of the total seasonal volume used for irrigation is diverted in March and 8.4 percent in April.

In 1953 there were 335 separate diversions, utilizing a combined total of 448 pumps, along the Sacramento River between Redding and Sacramento. In 1953, 294 diversions, including 371 pumps, were sur-

veyed. Factors which might influence the take of fish were listed. Twenty-three diversions were sampled intermittently for fish losses. In 1954, nine diversions near Colusa were sampled during the entire irrigation season.

Although some losses occurred during the entire irrigation seasons, the numbers of juvenile salmon and steelhead destroyed at individual diversions were quite small in 1953 and 1954. The greatest seasonal loss at one diversion consisted of about 2,000 young salmon and 110 yearling steelhead.

The small juvenile salmon losses encountered are not surprising, since fyke netting has shown that during years of normal runoff most of the fish migrate out of the upper river before the start of the main irrigation season. Evidence that considerable losses of adult salmon and steelhead occur at pump intakes which do not have trash grids or screens was gathered.

The adult king salmon migrations in the San Joaquin River system during recent years have consisted almost entirely of fall-run fish which spawn in the tributaries from the Merced to the Cosumnes rivers. The once large upper San Joaquin spring run was destroyed by 1949 as a result of the lack of flow releases from Friant Dam. The present fall run usually takes place a few weeks later than the Sacramento River fall run.

The seaward migration of San Joaquin River juvenile salmon usually peaks in the Stockton area some time in March.

The irrigation season along the San Joaquin River between the mouth of the Merced River and Stockton usually runs from early March through October, with some water diverted in February and November. On the average, about 5.8 percent of the water used for irrigation is diverted in March and 14.1 percent in April.

In 1955 there were 113 separate diversions, utilizing 159 pumps, along the San Joaquin River between Stockton and Newman (Fremont Ford). Three diversions were sampled during the time of the salmon fingerling seaward migration. All were found to be destroying more fingerling salmon than any of those sampled during the previous two years along the upper Sacramento. The expectancy of fish losses in diversions along the San Joaquin is illustrated not only by the coincidence of the irrigation season with the salmon migration, but also by the large proportion of San Joaquin flows which is diverted early in the irrigation season, during the salmon migration period.

A limited amount of diversion sampling was done in the Sacramento-San Joaquin River Delta in April, May and June, 1955, at pumps as well as siphons. All sampled diversions were found to be taking fingerling salmon.

By the end of June the last salmon fingerlings from the two river systems have usually entered the Delta. The seaward movement from the Delta is measurable through July. Close to 80 percent of the migrants pass through the Delta during March.

Many juvenile salmon pass through the pumps alive. In general, the centrifugal type pump appears to pass more fish alive than the screw type.

In 1956 and 1957, diversion sampling was also done on Butte Creek. Butte Creek supports an early spring run of adult king salmon. The fall run is small.

The seaward migration of fingerling salmon in Butte Creek occurred from the latter part of December through the early part of March in 1957, with practically all of the fish having moved out of the upper reaches by the end of February.

The normal irrigation season along Butte Creek extends from late April to late September.

There are eight large unscreened diversions on Butte Creek near Chico. Fyke nets were fished in two of these diversions, as well as at two points in the stream. The study showed that practically all of the fingerling salmon migrated out of the stream before the irrigation seasons started in 1956 and 1957. These results are in conflict with the findings of studies made in 1955, which showed that fingerling salmon losses in these same diversions occurred as late as mid-April.

The loss of adult salmon in Butte Creek diversions, particularly the Western Canal Company ditch, was demonstrated in 1956 and 1957. It is concluded that screens are necessary to protect them.

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APPENDIX

TABLE A-1

List of Common and Scientific Names of Fishes Captured in Fyke Nets During the Irrigation Diversion Survey

Common name	Scientific name
Family Petromyzontidae. The Lamprey Family.	
1. Pacific lamprey	*Entosphenus tridentatus* (Gairdner)
2. Brook lamprey	*Lampetra planeri* (Bloch)
Family Acipenseridae. The Sturgeon Family.	
3. White sturgeon	*Acipenser transmontanus* Richardson
Family Clupeidae. The Herring Family.	
4. American shad	*Alosa sapidissima* (Wilson)
Family Osmeridae. The Smelt Family.	
5.	Unknown
Family Salmonidae. The Salmon and Trout Family.	
6. King salmon	*Oncorhynchus tshawytscha* (Walbaum)
7. Steelhead rainbow trout	*Salmo gairdnerii gairdnerii* Richardson
Family Catostomidae. The Sucker Family.	
8. Sacramento western sucker	*Catostomus occidentalis occidentalis* Ayres
Family Cyprinidae. The Carp or Minnow Family.	
9. Carp	*Cyprinus carpio* Linnaeus
10. Sacramento blackfish	*Orthodon microlepidotus* (Ayres)
11. Sacramento hitch	*Lavinia exilicauda exilicauda* Baird and Girard
12. Sacramento squawfish	*Ptychocheilus grandis* (Ayres)
13. Splittail	*Pogonichthys macrolepidotus* (Ayres)
Family Ictaluridae. The Catfish Family.	
14. Channel catfish	*Ictalurus punctatus* (Rafinesque)
15. White catfish	*Ictalurus catus* (Linnaeus)
16. Brown bullhead	*Ictalurus nebulosus* (LeSueur)
Family Poeciliidae. The Topminnow Family.	
17. Mosquitofish	*Gambusia affinis* (Baird and Girar
Family Pleuronectidae. The Righteyed Flounder Family.	
18. Starry flounder	*Platichthys stellatus* (Pallas)
Family Serranidae. The Sea Bass Family.	
19. Striped bass	*Roccus saxatilis* (Walbaum)
Family Centrarchidae. The Sunfish Family.	
20. Largemouth bass	*Micropterus salmoides* (Lacé pè de)
21. Warmouth bass	*Chaenobryttus gulosus* (Cuvier)
22. Green sunfish	*Lepomis cyanellus* Rafinesque
23. Bluegill	*Lepomis macrochirus* Rafinesque
24. Black crappie	*Pomoxis migromaculatus* (LeSueur)
Family Embiotocidae. The Viviparous Perch Family.	
25. Tule perch	*Hysterocarpus traskii* Gibbons
Family Cottidae. The Sculpin Family.	
26. Sculpin	*Cottus* sp.
Family Gasterosteidae. The Stickleback Family.	
27. Threespine stickleback	*Gasterosteus aculeatus* Linnaeus

TABLE A-2

Sacramento River Irrigation Pump Survey, 1953

Size of pump (diameter in inches)	Number of pumps surveyed*				Number of pumps listed†		
	Turbine	Centrifugal	Screw type	Total	Diverting water	Not diverting water	Total
1¼	1	--	--	1	1	--	1
1½	--	2	--	2	2	--	2
2	--	1	--	1	3	1	4
2½	--	4	-	4	5	--	5
3		6	-	6	4	2	6
4		8	-	8	9	2	11
5	--	7	--	7	11	1	12
6	1	28	--	29	25	11	36
7		3	--	3	2	2	4
8	4	28	2	34	35	5	40
10	10	36	1	47	45	8	53
12	16	37	8	61	56	8	64
14	14	12	7	33	31	5	36
15	--	5	--	5	5	1	6
16	27	8	1	36	37	4	41
18	3	11	1	15	16	2	18
20	10	8	1	19	23	1	24
22	4	1	--	5	5	--	5
24	10	16	--	26	35	--	35
28		-	--	--	1	--	1
30	2	1	-	3	3	--	3
32	2	--	--	2	2	--	2
36	1	6	--	7	8	--	8
38		--	--	--	2	--	2
42	5	7	--	12	12	--	12
48	2	--	--	2	4	--	4
50	--	3	--	3	4	--	4
54	--	--	--	--	1	--	1
66	--	--	--	--	4	--	4
72	--	--	--	--	3	--	3
100	--	--	--	--	1	--	1
Totals	112	238	21	371	395	53	448

* It was not determined whether the turbines had centrifugal or screw-type runners because only external examination of the pump was possible. The screw-type pumps may also have been turbines but this was not determined for the same reason.

† Report of Sacramento-San Joaquin Water Supervision for 1953.

TABLE A-3

Sacramento River, Diversion Sampling: Number of Fish Trapped in the Canal During the 1953 Irrigation Season

Species of fish captured (common name)	Anderson-Cottonwood Irrigation District[1]	Olive Percy Davis et al. 78.8 R[2]	Reclamation District No. 1004	R. Pheiffer
	Apr. 6-Aug. 20	July 27-Aug. 13	June 3-18	May 28-30
King salmon (Fork length in inches)				No fish captured
1.0-1.4	17			
1.5-1.9	34			
2.0-2.4				
2.5-2.9				
3.0-3.4		1		
3.5-3.9		1	1	
4.0-4.4		3		
4.5-4.9		11		
5.0-5.4		7		
5.5-5.9		2		
6.0-6.4		1		
Not measured	85			
Totals	136	26	1	
Adult king salmon				
Steelhead rainbow trout				
Pacific lamprey		1	1	
Brook lamprey				
Ammocoete (species?)	2	1		
American shad				
Sacramento western sucker		382		
Carp		146		
Sacramento squawfish				
Splittail		2		
Unidentified minnows		362		
White catfish	6	22	1	
Mosquitofish		3		
Largemouth bass		7		
Green sunfish		1,785	1	
Warmouth				
Tule perch		2		
Sculpin (species?)		130	5	
Threespine stickleback	23			
Tadpole				
Crayfish		1	9	

[1] All of the king salmon were captured during the period April 6-16, 1953. Combined catch of two nets.

[2] Pump broke down during night of July 27; time unkown. An estimated 2,500 sunfish, minnows and suckers trapped on July 29 are not included in these totals.

TABLE A-3—Continued

Sacramento River, Diversion Sampling: Number of Fish Trapped in the Canal During the 1953 Irrigation Season

Species of fish captured (common name)	V. G. Strain	Provident Irrigation District	Princeton-Codora Glenn Irrigation District 123.9 R[3]	Princeton-Codora Glenn Irrigation District 112.4 R
	June 16-17	June 23-25	June 2-4	June 3-9
King salmon (Fork length in inches)	No fish captured			
1.0-1.4				
1.5-1.9				
2.0-2.4				
2.5-2.9				
3.0-3.4				
3.5-3.9				
4.0-4.4				
4.5-4.9				
5.0-5.4				
5.5-5.9				
6.0-6.4				
Not measured				
Totals				
Adult king salmon				
Steelhead rainbow trout				
Pacific lamprey				
Brook lamprey			1	5
Ammocoete (species?)				
American shad				
Sacramento western sucker				
Carp				
Sacramento squawfish		1		
Splittail				
Unidentified minnows		4		1
White catfish				2
Mosquitofish				
Largemouth bass				
Green sunfish				
Warmouth				
Tule perch			1	
Sculpin (species?)		1		4
Threespine stickleback		14		
Tadpole		2		16
Crayfish		1		1

[3] Combined catch of two nets.

TABLE A-3—Continued

Sacramento River, Diversion Sampling: Number of Fish Trapped in the Canal During the 1953 Irrigation Season

Species of fish captured (common name)	Hollis Sartain	Azro N. Lewis	Roger Wilbur 95.25 L[4]	Roger Wilbur 87.4 R[5]
	July 29-30	Aug. 10-13	July 28-30	July 27-28
King salmon (Fork length in inches)	No fish captured		No fish captured	
1.0-1.4				
1.5-1.9				
2.0-2.4				
2.5-2.9				
3.0-3.4				
3.5-3.9				
4.0-4.4				
4.5-4.9				
5.0-5.4				
5.5-5.9				
6.0-6.4				
Not measured				
Totals				
Adult king salmon				
Steelhead rainbow trout				
Pacific lamprey				
Brook lamprey				
Ammocoete (species?)				
American shad				
Sacramento western sucker		1		
Carp		43		1
Sacramento squawfish				
Splittail				
Unidentified minnows				
White catfish				
Mosquitofish				
Largemouth bass				
Green sunfish		4		
Warmouth				
Tule perch				
Sculpin (species?)				1
Threespine stickleback				
Tadpole				
Crayfish				

[4] Not enough velocity to make a good set; periodic water changing among ditches.
[5] Entire discharge sampled.

TABLE A-3—Continued

Sacramento River, Diversion Sampling: Number of Fish Trapped in the Canal During the 1953 Irrigation Season

Species of fish captured (common name)	Wayne Hall	Meridian Farms Water Company No. 1 and No. 2	Olive Percy Davis et al. 78.75 R	Robert Chesney J. H. Yates Estate[6]
	July 14-17	July 15-17	Aug. 10-13	July 14-17
King salmon (Fork length in inches)				
1.0-1.4				
1.5-1.9				
2.0-2.4				
2.5-2.9				
3.0-3.4				
3.5-3.9				
4.0-4.4				
4.5-4.9				
5.0-5.4				
5.5-5.9				
6.0-6.4				
Not measured				
Totals				
Adult king salmon				
Steelhead rainbow trout				
Pacific lamprey		1		
Brook lamprey		1		
Ammocoete (species?)		1		
American shad				
Sacramento western sucker	5	1	2	1
Carp	7	4		23
Sacramento squawfish	2	1		1
Splittail			1	
Unidentified minnows		1	2	
White catfish	3	1		120
Mosquitofish				
Largemouth bass				
Green sunfish	2	1	34	2
Warmouth				
Tule perch			2	
Sculpin (species?)			2	1
Threespine stickleback				
Tadpole				
Crayfish	27	25		10

[6] These pumps discharge into the same basin, both pumps were operating during sampling.

TABLE A-3—Continued

Sacramento River, Diversion Sampling: Number of Fish Trapped in the Canal During the 1953 Irrigation Season

Species of fish captured (common name)	Meridian Farms Water Company No. 3	Meridian Farms Water Company No. 4[7]	Faxon, Morton and P. Andreotti	J. L. Browning[8]
	July 15-17	Aug. 10-13	July 27-30	July 28
King salmon (Fork length in inches)				
1.0-1.4				
1.5-1.9				
2.0-2.4				
2.5-2.9				
3.0-3.4				
3.5-3.9				
4.0-4.4				
4.5-4.9				
5.0-5.4				
5.5-5.9				
6.0-6.4				
Not measured				
Totals				
Adult king salmon		22		
Steelhead rainbow trout		1		
Pacific lamprey				No fish captured
Brook lamprey				
Ammocoete (species?)				
American shad				
Sacramento western sucker			1	
Carp			1	
Sacramento squawfish				
Splittail				
Unidentified minnows			1	
White catfish				
Mosquitofish				
Largemouth bass				
Green sunfish				
Warmouth				
Tule perch	1	2	1	
Sculpin (species?)				
Threespine stickleback				
Tadpole				
Crayfish			1	

[7] An estimated 60-70 dead salmonids (6-24 inches in length) observed in ditch August 10-12, 1953.
[8] Only the 14-inch pump operated during sampling.

TABLE A-3—Continued

Sacramento River, Diversion Sampling: Number of Fish Trapped in the Canal During the 1953 Irrigation Season

Species of fish captured (common name)	Newhall Land and Farming Company	Natomas Central Mutual Water Company
	July 14-17	Aug. 18-19
King salmon (fork length in inches)		
1.0-1.4		
1.5-1.9		
2.0-2.4		
2.5-2.9		
3.0-3.4		
3.5-3.9		
4.0-4.4		
4.5-4.9		
5.0-5.4		
5.5-5.9		
6.0-6.4		
Not measured		
Totals		
Adult king salmon		
Steelhead rainbow trout		
Pacific lamprey		
Brook lamprey		
Ammocoete (species ?)	2	
American shad		1
Sacramento western sucker		
Carp	16	1
Sacramento squawfish		
Splittail		
Unidentified minnows	39	
White catfish	2	2
Mosquitofish		
Largemouth bass		
Green sunfish	1	
Warmouth		1
Tule perch		
Sculpin (species?)	1	
Threespine stickleback		
Tadpole	1	
Crayfish	1	

TABLE A-4

Sacramento River; Olive Percy Davis et al. Diversion, 78.8 R *: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9	2												2
2.0-2.4	3	17	1										21
2.5-2.9	6	18	6					1					31
3.0-3.4	3	25	11	3	15	1	1						59
3.5-3.9		8	16	14	36	12	4	1					91
4.0-4.4		2	4	8	9	9	12	1					45
4.5-4.9				2	1	2	1	1	1				8
5.0-5.4		1	1				1						3
Not measured	1	17	3	9	7	3			3				43
Totals	15	88	42	36	68	27	19	4	4				303
Adult king salmon										1			1
Steelhead rainbow trout	3	11	1		4				1				20
Pacific lamprey	7	8	1	9	80	24	6	8	2				145
Brook lamprey	58	150	41	3	7								259
Ammocoete (species?)	5	1					1						7
White sturgeon		2			1								3
American shad													
Sacramento western sucker	1	4	7	1	6		17	4	17	14			71
Carp	30	164	2	46	234	198	127	80	34	18			933
Sacramento blackfish													
Sacramento hitch					1								1
Sacramento squawfish	1	7											8
Splittail													
Unidentified minnows	8	152	3	17	330	392	36	17	13	3			971
Channel catfish						2	1	3					6
White catfish	7	24	8	14	68	42	24	11	3	10			211
Brown bullhead		1				11		1					13
Mosquitofish					1								1
Striped bass		1						1					2
Largemouth bass	3	97		1	45		2	3	2	6			159
Green sunfish	1	8	2	2	3	973	112	15	48	6			1,170
Bluegill													
Black crappie					9		1						10
Tule perch		2		1	4				1				8
Sculpin (species?)			1		22	50	35	4	3				115
Tadpole		7			3	1			1				12
Crayfish		11	6		4	2	2	1	1				27

* Mile and bank above Sacramento.

TABLE A-5

Sacramento River; Meridian Farms Water Company No. 1 and No. 2 Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25-May 8	May 9-22	May 23-June 5	June 6-19	June 20-July 3	July 4-17	July 18-31	Aug. 1-14	Aug. 15-28	Aug. 29-Sept. 11	Sept. 12-25	Sept. 26-Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9	1												1
2.0-2.4	11												11
2.5-2.9	8	1			1								10
3.0-3.4		2	1		2								5
3.5-3.9													
4.0-4.4													
4.5-4.9													
5.0-5.4													
Not measured	1				3								4
Totals	21	3	1		6								31
Adult king salmon		1			1	1	1	2	1	2	1		10
Steelhead rainbow trout	4					3		1	1				9
Pacific lamprey	10	1	1	1	16	7	7	3					46
Brook lamprey	185	28	13	5	5	1							237
Ammocoete (species?)	4	5	2	6	9	1	3	6	4	2			42
White sturgeon													
American shad													
Sacramento western sucker	3		1	1	1	2	1	1	9	3			22
Carp	13	49	3	506	127	68	15	10	15	9	2		817
Sacramento blackfish	1	1		8	5	3							18
Sacramento hitch							1		2	1	11		15
Sacramento squawfish	1			1									5
Splittail						1							1
Unidentified minnows	5	1	1		2	2	6	2		1	1		21
Channel catfish		2	1	1	1	2		3					10
White catfish	35	27	11	19	128	69	90	59	23	29	19		509
Brown bullhead	3	1			40	188	7			4	2		245
Mosquitofish													
Striped bass		52		2	1				1				56
Largemouth bass	7	59			4						1		71
Green sunfish	7	1		2	2	2	2	2		2			20
Bluegill	1												1
Black crappie			1	1									2
Tule perch	6	2		3	8	1	3	4	3	5			35
Sculpin (species?)	6	1	2	5	11	3	4	2	2	2			38
Tadpole	1	9	2	1	2						1		16
Crayfish	62	99	70	158	290	91	64	92	91	47	11		1,075

TABLE A-6

Sacramento River; St. Patrick Home Ranch Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	Mar. 1-13	Mar. 14-27	Mar. 28-Apr. 10	Apr. 11-24	Apr. 25-May 8	May 9-22	May 23-June 5	June 6-19	June 20-July 3	July 4-17	July 18-31	Aug. 1-14	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4	202	24			21								247
1.5-1.9	438	126			32								596
2.0-2.4	9	7											16
2.5-2.9	1	1				2							4
3.0-3.4													
3.5-3.9													
4.0-4.4	2												2
4.5-4.9													
5.0-5.4													
Not measured	389	11			1								401
Totals	1,041	169			54	2							1,266
Adult king salmon	1												1
Steelhead rainbow trout	1				1								2
Pacific lamprey	10	15			2								27
Brook lamprey	5												5
Ammocoete (species?)	32	4			4	11							51
White sturgeon													
American shad													
Sacramento western sucker	11				2	8				1			22
Carp						4				3			7
Sacramento blackfish													
Sacramento hitch	1												1
Sacramento squawfish	2												2
Splittail													
Unidentified minnows													
Channel catfish													
White catfish	1					21				11	1		34
Brown bullhead	1												1
Mosquitofish													
Striped bass										2			2
Largemouth bass													
Green sunfish		1											1
Bluegill													
Black crappie													
Tule perch	3					7				1			11
Sculpin (species?)	8	1			1	3				2	1		16
Tadpole													
Crayfish	2					8				5	3		18

TABLE A-7

Sacramento River; Wayne Hall Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9													
2.0-2.4													
2.5-2.9													
3.0-3.4													
3.5-3.9													
4.0-4.4													
4.5-4.9													
5.0-5.4													
Not measured				1									1
Totals				1									1
Adult king salmon													
Steelhead rainbow trout													
Pacific lamprey													
Brook lamprey													
Ammocoete (species?)					1		2		1	3	2		9
White sturgeon													
American shad													
Sacramento western sucker				1	45	113	23	4	4	16	1		207
Carp				49	11	9	2	39	12	14	110	9	255
Sacramento blackfish													
Sacramento hitch								1		10	1		12
Sacramento squawfish								2					2
Splittail								1					1
Unidentified minnows				60	32	87	2	19	8		4		212
Channel catfish													
White catfish				13	19	21	3	7	2	1	5	2	73
Brown bullhead					7	8	1		1		1		18
Mosquitofish													
Striped bass													
Largemouth bass				4	1			13	11	5	3		37
Green sunfish											1	5	6
Bluegill													
Black crappie									1				1
Tule perch				3	4	1		4					12
Sculpin (species?)				3	2		1	3	2	3			14
Tadpole							1						1
Crayfish				62	81	50	19	31	46	43	58	16	406

TABLE A-8

Sacramento River; Olive Percy Davis et al. Diversion, 78.75 R *: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9													
2.0-2.4													
2.5-2.9													
3.0-3.4				2									2
3.5-3.9				11									11
4.0-4.4				4									4
4.5-4.9													
5.0-5.4													
Not measured		1											1
Totals		1		17									18
Adult king salmon													
Steelhead rainbow trout													
Pacific lamprey		4											4
Brook lamprey	9	37		1									47
Ammocoete (species?)		1											1
White sturgeon													
American shad													
Sacramento western sucker		1		1									2
Carp		31											31
Sacramento blackfish													
Sacramento hitch													
Sacramento squawfish													
Splittail													
Unidentified minnows	3			1									4
Channel catfish													
White catfish		2		3									5
Brown bullhead													
Mosquitofish													
Striped bass		61											61
Largemouth bass		23											23
Green sunfish		4											4
Bluegill													
Black crappie													
Tule perch		2											2
Sculpin (species?)													
Tadpole		3											3
Crayfish		3		3									6

* Mile and bank above Sacramento.

TABLE A-9

Sacramento River; Meridian Farms Water Company No. 3 Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9		1											1
2.0-2.4													
2.5-2.9													
3.0-3.4													
3.5-3.9													
4.0-4.4													
4.5-4.9													
5.0-5.4													
Not measured	1												1
Totals	1	1											2
Adult king salmon													
Steelhead rainbow trout													
Pacific lamprey													
Brook lamprey	1												1
Ammocoete (species?)	3	3	1			2	3	1					13
White sturgeon													
American shad													
Sacramento western sucker								2	2	1			5
Carp	1	7	8	13	8	1	1						39
Sacramento blackfish													
Sacramento hitch													
Sacramento squawfish													
Splittail													
Unidentified minnows		4	6	6	4	1							21
Channel catfish													
White catfish		1		1	4	9	1	3	1				20
Brown bullhead							6	1	3				10
Mosquitofish							1						1
Striped bass		65											65
Largemouth bass	6	41	1	1	4			1					54
Green sunfish	1	22	18		1	1							43
Bluegill	1												1
Black crappie		36	21	17	3			1					78
Tule perch		1	2	12	3		1	1	1				21
Sculpin (species?)	3	2	1	3	2		1	2	1		1		16
Tadpole	4	19	12	9	3								47
Crayfish	4	15	9	20	18	2	4	5	1	1			79

TABLE A-10

Sacramento River; Meridian Farms Water Company No. 4 Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9													
2.0-2.4													
2.5-2.9		1											1
3.0-3.4													
3.5-3.9													
4.0-4.4													
4.5-4.9													
5.0-5.4													
Not measured		1											1
Totals		2											2
Adult king salmon													
Steelhead rainbow trout													
Pacific lamprey	1	1											2
Brook lamprey	34	6											40
Ammocoete (species?)	3	1											4
White sturgeon													
American shad													
Sacramento western sucker		1											1
Carp		5											5
Sacramento blackfish													
Sacramento hitch													
Sacramento squawfish		1											1
Splittail													
Unidentified minnows		6											6
Channel catfish													
White catfish	11	4											15
Brown bullhead		2											2
Mosquitofish													
Striped bass		3											3
Largemouth bass		24											24
Green sunfish		2											2
Bluegill													
Black crappie													
Tule perch	4	1											5
Sculpin (species?)	6												6
Tadpole		3											3
Crayfish	9	11											20

TABLE A-11

Sacramento River; Hoffman, Beckley, Ritchie, Poundstone, and Andreotti Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	Mar. 28–April 10	April 11-24	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9													
2.0-2.4													
2.5-2.9													
3.0-3.4							1						1
3.5-3.9													
4.0-4.4									1				1
4.5-4.9													
5.0-5.4									1				1
Not measured													
Totals							1		2				3
Adult king salmon													
Steelhead rainbow trout								1		1			2
Pacific lamprey													
Brook lamprey		2											2
Ammocoete (species?)							1						1
White sturgeon													
American shad													
Sacramento western sucker						5	5			2	5	6	23
Carp						5	9	5	2	3	2	2	28
Sacramento blackfish											2		2
Sacramento hitch											39	17	56
Sacramento squawfish													
Splittail											1		1
Unidentified minnows						5	303	9	24	47	22		410
Channel catfish								2		1		1	4
White catfish						14	24	19	25	41	15	5	143
Brown bullhead						1	1			2	1	2	7
Mosquitofish											1		1
Striped bass													
Largemouth bass							3		1			1	5
Green sunfish													
Bluegill													
Black crappie						1							1
Tule perch						1	2	2		1	8	1	15
Sculpin (species?)							9			1	2	1	13
Tadpole							3						3
Crayfish		1				16	31	8	23	22	19		120

TABLE A-12

Sacramento River; Faxon, Morton, and P. Andreotti Diversion: Number of Fished Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9													
2.0-2.4													
2.5-2.9													
3.0-3.4													
3.5-3.9													
4.0-4.4													
4.5-4.9													
5.0-5.4													
Not measured													
Totals													
Adult king salmon													
Steelhead rainbow trout									1				1
Pacific lamprey													
Brook lamprey													
Ammocoete (species?)				5	7	2	5	4	3				26
White sturgeon													
American shad					2								2
Sacramento western sucker							2	2	27	1			32
Carp				25	57	12	9	5	3				111
Sacramento blackfish					2								2
Sacramento hitch										1			1
Sacramento squawfish													
Splittail													
Unidentified minnows				1	1		3		1	1			7
Channel catfish													
White catfish				1	15	7	9	3	2				37
Brown bullhead													
Mosquitofish													
Striped bass					4		1						5
Largemouth bass					1								1
Green sunfish				1	1	1							3
Bluegill													
Black crappie													
Tule perch				2	10		8	3	13				36
Sculpin (species?)					3	2	1	1	1	2			10
Tadpole				1									1
Crayfish				1	42	18	23	31	22	6			143

TABLE A-13

Sacramento River; Tisdale Irrigation and Drainage Company Diversion, 67.1 L*: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9													
2.0-2.4													
2.5-2.9													
3.0-3.4													
3.5-3.9													
4.0-4.4													
4.5-4.9													
5.0-5.4													
Not measured													
Totals													
Adult king salmon													
Steelhead rainbow trout	2												
Pacific lamprey													
Brook lamprey	1		1										2
Ammocoete (species?)	4	1											5
White sturgeon													
American shad													
Sacramento western sucker													
Carp	1	18	14	10									43
Sacramento blackfish													
Sacramento hitch													
Sacramento squawfish													
Splittail													
Unidentified minnows	39	2		1									42
Channel catfish													
White catfish	2	1											3
Brown bullhead													
Mosquitofish													
Striped bass		62											62
Largemouth bass	4	11											15
Green sunfish				1									1
Bluegill		8											8
Black crappie		3	10										13
Tule perch			1										1
Sculpin (species?)		1											1
Tadpole			1	1									2
Crayfish			1										1

* Mile and bank above Sacramento.

TABLE A-14

Sacramento River; Sutter Mutual Water Company Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9													
2.0-2.4					1								1
2.5-2.9			9	1									10
3.0-3.4			12	2	1	1							16
3.5-3.9			3	2		1							6
4.0-4.4							1						1
4.5-4.9									1				1
5.0-5.4													
Not measured			3	1		3	1	1					9
Totals			27	6	2	5	2	1	1				44
Adult king salmon													
Steelhead rainbow trout													
Pacific lamprey													
Brook lamprey			13	1									14
Ammocoete (species?)			6	1			4		2				13
White sturgeon													
American shad													
Sacramento western sucker							1		6				7
Carp			1	58	27	30	41	19	17		1		194
Sacramento blackfish				3					1		1		5
Sacramento hitch													
Sacramento squawfish					1								1
Splittail													
Unidentified minnows			2	8	1	1	5						17
Channel catfish													
White catfish			4	1	1	2	7	2	1				18
Brown bullhead													
Mosquitofish													
Striped bass													
Largemouth bass			1		1	3			1		1		7
Green sunfish				8	5	3	10	1	3				30
Bluegill				1		1							2
Black crappie				2				1			1		4
Tule perch			1	15	11	2	4	3	1		1		38
Sculpin (species?)			1				2						3
Tadpole			5	1			2						8
Crayfish			2	27	122	63	65	46	17				342

TABLE A-15

Sacramento River; W. A. Larner Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9													
2.0-2.4													
2.5-2.9													
3.0-3.4			1										1
3.5-3.9													
4.0-4.4													
4.5-4.9													
5.0-5.4													
Not measured				1									1
Totals			1	1									2
Adult king salmon													
Steelhead rainbow trout													
Pacific lamprey		1							1				2
Brook lamprey			1	5									6
Ammocoete (species?)			3	2	6		1						12
White sturgeon													
American shad													
Sacramento western sucker											1		1
Carp		3	3	28	3	3					14	2	56
Sacramento blackfish					1								1
Sacramento hitch													
Sacramento squawfish													
Splittail													
Unidentified minnows				4	3								7
Channel catfish											1		1
White catfish		4	6	22	10	10	7	25	3		1		88
Brown bullhead							1						1
Mosquitofish													
Striped bass					1	1	1						3
Largemouth bass		32	1		2								35
Green sunfish		2	2	1	5		1	2	1		1	2	17
Bluegill													
Black crappie				1									1
Tule perch			10	23	14	4	2	2	1	1	2		59
Sculpin (species?)					1								1
Tadpole			1	1									2
Crayfish													
		18	28	54	65	24	32	34	20	10	20	4	309

TABLE A-16

Sacramento River; Thousand Acre Ranch (H. W. Keller) Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9	3												3
2.0-2.4													
2.5-2.9	1												1
3.0-3.4													
3.5-3.9													
4.0-4.4													
4.5-4.9													
5.0-5.4													
Not measured													
Totals	4												4
Adult king salmon													
Steelhead rainbow trout													
Pacific lamprey	5												5
Brook lamprey	4												4
Ammocoete (species?)													
White sturgeon													
American shad													
Sacramento western sucker													
Carp			15										15
Sacramento blackfish													
Sacramento hitch													
Sacramento squawfish			1										1
Splittail													
Unidentified minnows	3	4	1										8
Channel catfish													
White catfish	2												2
Brown bullhead													
Mosquitofish													
Striped bass		1											1
Largemouth bass													
Green sunfish		1											1
Bluegill	1												1
Black crappie													
Tule perch													
Sculpin (species?)	1												1
Tadpole													
Crayfish													

TABLE A-17

Sacramento River; Diversion Sampling: Number of Fish Trapped in the Canals During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	Reclamation District No. 1004	Charles W. Welch	Nettie, George and Ella Packer		Mayfair Packing Company	Howell Davis
	Apr. 25-May 8	Apr. 25-May 8	May 9-22	May 23-June 5	Sept. 26-Oct. 9	July 4-17
King salmon (Fork length in inches)						
1.0-1.4						
1.5-1.9	2					
2.0-2.4	1					
2.5-2.9	1			1		
3.0-3.4						
3.5-3.9						
4.0-4.4						
4.5-4.9						
5.0-5.4						
Not measured	1	2				
Totals	5	2		1		
Adult king salmon						
Steelhead rainbow trout						
Pacific lamprey	1					
Brook lamprey	1					
Ammocoete (species?)	2	1	25	7		
White sturgeon						
American shad						
Sacramento western sucker	1					
Carp	1	7		1		
Sacramento blackfish						
Sacramento hitch						
Sacramento squawfish		1				
Splittail						
Unidentified minnows		2				
Channel catfish						
White catfish	2		3			
Brown bullhead		2				
Mosquitofish						
Striped bass						
Largemouth bass			1			
Green sunfish		5	1			
Bluegill		1	1			
Black crappie						
Tule perch	1				1	1
Sculpin (species?)	3	1	2	1		
Tadpole	4	2	5	1		
Crayfish	2		2		1	1

TABLE A-17—Continued

Sacramento River; Diversion Sampling: Number of Fish Trapped in the Canals During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	J. H. Yates Estate	Newhall Land and Farming Company	Tisdale Irrigation and Drainage Company 64.4 L*			Sacramento River Ranch
	May 9-22	Apr. 25-May 8	May 23-June 5	Aug. 15-28	Sept. 12-25	May 9-22
King salmon (Fork length in inches)						
1.0-1.4						
1.5-1.9						
2.0-2.4						
2.5-2.9						3
3.0-3.4						1
3.5-3.9						1
4.0-4.4						
4.5-4.9						
5.0-5.4						
Not measured						2
Totals						7
Adult king salmon		1				
Steelhead rainbow trout						2
Pacific lamprey		3				1
Brook lamprey		39				
Ammocoete (species?)			2			
White sturgeon						
American shad						2
Sacramento western sucker						
Carp		10				9
Sacramento blackfish						
Sacramento hitch						
Sacramento squawfish						
Splittail						
Unidentified minnows		6				
Channel catfish						
White catfish	1	7	1		1	2
Brown bullhead		3				
Mosquitofish						
Striped bass	1	1				
Largemouth bass		5				1
Green sunfish						
Bluegill						
Black crappie						
Tule perch	1					
Sculpin (species?)		3				
Tadpole						
Crayfish		14	10	3	10	

* Mile and bank above Sacramento.

TABLE A-18

Sacramento River; Diversion Sampling: Number of Fish Trapped in Canals During the 1955 Irrigation Season by Two-week Periods

Species of fish captured (common name)	L. W. Seaver 99.3 R*	Meridian Farms Water Company No. 1 and No. 2, 80.0 L*	
	Mar. 6-19	Mar. 20-Apr. 2	Apr. 3-16
King salmon (Fork length in inches)			
1.0-1.4	2	1	
1.5-1.9		2	
2.0-2.4		1	
2.5-2.9		2	
3.0-3.4			
3.5-3.9		1	
4.0-4.4			
4.5-4.9			
5.0-5.4			
Not measured			
Totals	2	7	
Adult king salmon			
Steelhead rainbow trout	1		
Pacific lamprey			
Brook lamprey			
Ammocoete (species?)			
White sturgeon			
American shad			
Sacramento western sucker			
Carp			
Sacramento blackfish		3	5
Sacramento hitch			
Sacramento squawfish			
Splittail			
Unidentified minnows			
Channel catfish			
White catfish			
Brown bullhead			
Mosquitofish			
Striped bass			
Largemouth bass			
Green sunfish			
Bluegill			
Black crappie			
Tule perch			
Sculpin (species?)			
Tadpole		7	
Crayfish	3	2	19

* Mile and bank above Sacramento.

TABLE A-19

San Joaquin River; Banta-Carbona Irrigation District: Number of Fish Trapped in the Canal During the 1955 Irrigation Season by Two-week Periods

Species of fish captured (common name)	Mar. 20-April 2	April 3-16	April 17-30	May 1-14	May 15-28	Seasonal total
King salmon (Fork length in inches)						
1.0-1.4	13	1				14
1.5-1.9	58	22				80
2.0-2.4	19	80	18	7		124
2.5-2.9	6	95	24	13		138
3.0-3.4		27	6	2		35
3.5-3.9		1		1		2
4.0-4.4						
4.5-4.9						
5.0-5.4						
5.5-5.9						
6.0-6.4						
Not measured		1				1
Totals	96	227	48	23		394
Steelhead rainbow trout						
Pacific lamprey						
Brook lamprey						
Ammocoete (species?)		10	12			22
American shad		2				2
Smelt (species?)						
Carp						
Splittail				1		1
Unidentified minnows	7	3	2		1	13
Channel catfish						
White catfish	4	8	4	1	4	21
Brown bullhead		2				2
Mosquitofish	1		1			2
Starry flounder						
Striped bass	2	4	1	1		8
Largemouth bass						
Green sunfish	6	8				14
Warmouth						
Bluegill						
Black crappie		5	1	3		9
Tule perch						
Sculpin (species?)						
Threespine stickleback						
Tadpole	2					2
Crayfish						

TABLE A-20

San Joaquin River; El Solyo Water Company: Number of Fish Trapped in the Canal During the 1955 Irrigation Season by Two-week Periods

Species of fish captured (common name)	Mar. 20-April 2	April 3-16	April 17-30	May 1-14	May 15-28	May 29-June 11	Seasonal total
King salmon (Fork length in inches)							
1.0-1.4	14	1					15
1.5-1.9	22	15	4				21
2.0-2.4		8	27				35
2.5-2.9		1	10				11
3.0-3.4			1				1
3.5-3.9			1				1
4.0-4.4							
4.5-4.9							
5.0-5.4							
5.5-5.9							
6.0-6.4							
Not measured		1					1
Totals	36	26	43				105
Steelhead rainbow trout							
Pacific lamprey							
Brook lamprey							
Ammocoete (species?)							
American shad							
Smelt (species?)							
Carp		2	2	4	8		16
Splittail							
Unidentified minnows			2		1		3
Channel catfish							
White catfish	2	1	3		1		7
Brown bullhead							
Mosquitofish	2	5	12				19
Starry flounder							
Striped bass						1	1
Largemouth bass	1						1
Green sunfish	5	2	2		4		13
Warmouth							
Bluegill							
Black crappie			1				1
Tule perch							
Sculpin (species?)		1					1
Threespine stickleback							
Tadpole		2	1				3
Crayfish	2	2	2	1			7

TABLE A-21

San Joaquin River; Patterson Water Company: Number of Fish Trapped in the Canal During the 1955 Irrigation Season by Two-week Periods

Species of fish captured (common name)	Mar. 20-April 2	April 3-16	April 17-30	May 1-14	May 15-28	Seasonal total
King salmon (Fork length in inches)						
1.0-1.4			1			1
1.5-1.9						
2.0-2.4						
2.5-2.9	2	1		1		4
3.0-3.4	10	4				14
3.5-3.9	2					2
4.0-4.4						
4.5-4.9						
5.0-5.4						
5.5-5.9						
6.0-6.4						
Not measured						
Totals	14	5	1	1		21
Steelhead rainbow trout						
Pacific lamprey						
Brook lamprey						
Ammocoete (species?)			1			1
American shad						
Smelt (species?)						
Carp	3				1	4
Splittail	1				1	2
Unidentified minnows	9	2	1		1	13
Channel catfish						
White catfish	9	1	2	6	4	22
Brown bullhead						
Mosquitofish	1					1
Starry flounder						
Striped bass						
Largemouth bass						
Green sunfish	9				2	11
Warmouth						
Bluegill						
Black crappie		1			1	2
Tule perch						
Sculpin (species?)						
Threespine stickleback						
Tadpole		7	3	2	1	13
Crayfish	1		2	2	1	6

TABLE A-22

Sacramento-San Joaquin River Delta; East Contra Costa Irrigation District: Number of Fish Trapped in the Canal During the 1955 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 3-16	April 17-30	May 1-14	May 15-28	May 29-June 11	June 12-25	Seasonal total
King salmon (Fork length in inches)							
1.0-1.4							
1.5-1.9					2		2
2.0-2.4	1			2	2	2	7
2.5-2.9	4	4	9	24	16	10	67
3.0-3.4	2	16	16	30	23	5	92
3.5-3.9		13	2	3	3		21
4.0-4.4	1	6	1				8
4.5-4.9	2	2					4
5.0-5.4	2	3	1				6
5.5-5.9							
6.0-6.4		1					1
Not measured	2	1	12	4	3	1	23
Totals	14	46	41	63	49	18	231
Steelhead rainbow trout		1	1				2
Pacific lamprey			5				5
Brook lamprey							
Ammocoete (species?)		6		4	3		13
American shad							
Smelt (species?)	5	1			500		506
Carp		2	1	4	10		17
Splittail							
Unidentified minnows	6	1		2	3		12
Channel catfish							
White catfish	15	1	1	2	6		25
Brown bullhead							
Mosquitofish							
Starry flounder		2	2	7	8		19
Striped bass	3	1	1		2		7
Largemouth bass							
Green sunfish	10	7	4	3	10		34
Warmouth							
Bluegill							
Black crappie			1				1
Tule perch							
Sculpin (species?)	3		1	1	4		9
Threespine stickleback	1	1	1	2	2		7
Tadpole							
Crayfish	1						1

TABLE A-23

Sacramento-San Joaquin River Delta; Diversion Sampling: Number of Fish Trapped in Canals During the 1955 Irrigation Season

Species of fish captured (common name)	Contra Costa Canal Bureau of Reclamation		Reclamation District No. 501		Passaglia Brothers		Woodbridge Irrigation District			
	May 29-June 11	June 12-25	May 29-June 11	June 12-25	May 29-June 11	June 12-25	Mar. 20-Apr. 2	Apr. 3-16	Apr. 17-30	May 1-14
King salmon (Fork length in inches)										
1.0-1.4							1			
1.5-1.9										
2.0-2.4		1	4			2		2		
2.5-2.9	5	8	21	5		3				
3.0-3.4		4	12	5		3				
3.5-3.9			1		3	8				
4.0-4.4	1									
4.5-4.9										
5.0-5.4										
5.5-5.9										
6.0-6.4										
Not measured		1								
Totals	6	14	38	10	3	16	1	2		
Steelhead rainbow trout										
Pacific lamprey										
Brook lamprey					8	3				
Ammocoete (species?)							1	7	18	
American shad										
Smelt (species?)	30		10	1	6					
Carp			13		1					
Splittail										
Unidentified minnows			5	2		2				
Channel catfish					1					
White catfish		3	74	18	45	28				
Brown bullhead			5		2	1				
Mosquitofish										
Starry flounder	5									
Striped bass		4	1							
Largemouth bass										
Green sunfish		1	150	2	5	1	6	12	1	1
Warmouth						1				
Bluegill			1							
Black crappie					6					
Tule perch				1						
Sculpin (species?)	2			1						
Threespine stickleback	1									
Tadpole	2						8	1		
Crayfish			11							

TABLE A-24

Butte Creek; Diversion Sampling: Number of Fish Trapped in Canals During the 1957 Irrigation Season

Species of fish captured (common name)	Phelan-Parrott* Irrigation system					Durham Mutual Water Company, Ltd.				
	Jan. 6-19	Jan. 20-Feb. 2	Feb. 3-4	Feb. 17-Mar. 2	Seasonal total	Jan. 6-19	Jan. 20-Feb. 2	Feb. 3-16	Feb. 17-Mar. 2	Seasonal total
King salmon										
1.5-2.0 inches (fork length)		66	21		87			45	160	205
Not measured	31				31					
Totals	31	66	21		118			45	160	205
Pacific lamprey								1		1
Sacramento western sucker	1	3	1		5					
Unidentified minnows	4	45	14		63			2		2
Riffle sculpin			1		1					

* Often referred to as Parrott-Phelan.

END OF DOCUMENT

ATTACHMENT B

STATE OF CALIFORNIA—THE RESOURCES AGENCY

PETE WILSON, Governor

DEPARTMENT OF WATER RESOURCES

ENVIRONMENTAL SERVICES OFFICE
3251 S STREET
SACRAMENTO CA 95816-7017

029

December 28, 1992

Mr. Dante John Nomellini
Central Delta Water Agency
235 East Weber Avenue
Post Office Box 1461
Stockton, California 95201

Dear Mr. Nomellini:

As you requested, enclosed is some preliminary information regarding the fish screen on McDonald Island. The larval fish data I believe are reliable. The data on the juvenile and older fish I do not believe are reliable.

During our study on McDonald and other islands through the Delta, we experienced difficulties in trying to develop a rate of diversion for juvenile and older fish by agricultural siphons and pumps. It is likely that the juvenile and older fish were diverted into the irrigation ditch when the screen was not operating and established residence there. We then captured these fish when we started sampling, even though the screen was in operation. I say this because intuition and logic does not support the data. The only way to answer this question is to wrap a net around the siphon being tested. We plan on doing this where we can in 1993.

Eggs and larval fish unlike juvenile and older fish are planktonic, that is they float where the currents take them. Therefore it is much simpler to develop a rate of diversion for these organisms because you know that unlike the older fish, they are coming in with the flow. That is why I believe that the data on the larval fish are reliable.

As we discussed, I would like to find a site on McDonald Island or some other similarly located island in the Delta where an experimental fish screen can be attached to a 16-inch or 18-inch siphon. I would prefer that the siphon divert continuously or nearly so, through the irrigation period. The screen would be tested on an "off/on" basis, much like we did this year. Power would be brought to the site so the screen could operate on a self-cleaning mode. Lakos is one company willing to design such a screen if a suitable site can be found. It would be great if we could start collecting samples by mid-March, 1993. Dan Odenweller with the Department of Fish and Game supports this idea and is eager to work with us on it.

When we last talked, you indicated that you might be able to assist us in locating an appropriate site for screen testing. I would greatly appreciate your assistance in this. The information we can obtain from additional sampling under the right conditions would be of great value to the farmers, screen makers and water agencies. The preliminary data I am sending you confirms this to some degree.

If you have any questions concerning this letter or the enclosure, please feel free to call me at (916) 445-7203. I hope we can work together to find a suitable site and move on with the screen project.

Sincerely

Leo Winternitz

Leo Winternitz
Environmental Services Office

Enclosure

cc: Dan Odenweller
Department of Fish and Game
3251 "S" Street
Sacramento, California 95816

Paul Raquel
Department of Fish and Game
3251 "S" Street
Sacramento, California 95816

1992 AGRICULTURAL DIVERSION FISH IMPACT STUDY
MCDONALD TRACT

	NUMBER OF FISH CAUGHT					
	MAY - AUGUST			JUNE - AUGUST		
	Larval Fish			Juveniles and Older		
	*FISH SCREEN			*FISH SCREEN		
Species	**Off**	**On**	**Total**	**Off**	**On**	**Total**
Chameleon goby	1276	589	**1865**	0	0	**0**
Threadfin shad	1766	60	**1826**	0	0	**0**
Striped bass	0	0	**0**	0	0	**0**
Centrarchids	9	0	**9**	2[1]	1[2]	**3**
Delta smelt	0	0	**0**	0	0	**0**
Sacramento splittail	0	0	**0**	0	0	**0**
Mosquitofish	3	0	**3**	4	23	**27**
TOTALS:	3054	649	**3693**	6	24	**30**
Eggs:						
Striped bass	0	0	**0**	0	0	**0**
Threadfin shad	4	14	**18**	0	0	**0**
TOTAL EGGS:	4	14	**18**	0	0	**0**

---

[1] Green sunfish

[2] Bluegill

* Sampling Times were equal for Screen <u>off</u> and <u>on</u>.

END OF DOCUMENT

ATTACHMENT C

DIRECTORS
George Biagi, Jr.
Rudy Mussi
Alfred R. Zuckerman

COUNSEL
Dante John Nomellini
Thomas M. Zuckerman

CENTRAL DELTA WATER AGENCY

235 East Weber Avenue • P. O. Box 1461 • Stockton, CA 95201
Phone 209/465-5883

December 17, 1993

VIA AIRBORNE EXPRESS AND
FACSIMILE NO. (310) 980-4027

Gary Matlock
Acting Regional Director
NMFS, Southwest Region
501 West Ocean Boulevard, Suite 4200
Long Beach, California 90802-4213

Re: Advance notice of proposed rulemaking - Endangered Species, Screening of Water Diversions to Protect Sacramento River Winter-Run Chinook Salmon

Dear Sir:

The Central Delta Water Agency encompasses approximately 120,000 acres of primary agricultural lands within the central portion of the Sacramento/San Joaquin Delta. The boundaries of the agency are shown on the attached map.

Delta agricultural diversions vary as to time and duration and cannot be equated to Delta agricultural consumption or channel depletion.

Most of the land in the Central Delta Water Agency is below the level of the water in the adjoining channels and is irrigated by way of siphons. The water table is high and constant drainage pumping is needed to keep the water table below the surface of the ground. Although we do not have an accurate count of the number of diversions, we believe that the estimate of 1600 to 1800 for the Delta as a whole is probably correct. The time and duration of diversions through the various siphons and pumps varies substantially depending upon the area served, the crops, rainfall and availability of water due to seepage. The reference to Delta annual consumptive water use is misleading since much of the water needed by crops is provided by rainfall and seepage which do not involve the possibility of entrainment. In 1992, we conducted a fish screen test in cooperation with the California Department of Fish and Game, Department of Water Resources and the California Striped Bass Association on McDonald Island. The siphon which was picked for the test was a 12-inch siphon on Turner Cut which served a field planted to wheat. Due to the availability of moisture from rainfall and seepage, the farmer only diverted water through the siphon for a four (4) day period in the later part of May. Although we were allowed to operate the siphon at other times for test purposes, our experience highlights the need for a rational approach to screening based on evaluation of each diversion. The results of the test provided to us by DWR are attached. No Striped Bass, no Delta Smelt, no Sacramento Split Tail and no Salmon were diverted.

We are familiar with the DWR study by Randall Brown referenced in your notice. Although we agree with a number of his conclusions, we believe his assumptions as to the timing and magnitude of Delta diversions are in error and overstate the potential for entrainment of eggs, larvae and fish. Delta depletions which utilize moisture from rainfall or seepage cannot result in the diversion of eggs, larvae or fish. There is no substitute for proper testing and study by an unbiased party. Mr. Brown warns us with his statement, "I was forced to make a lot of assumptions and to stretch the available data past comfortable limits. Because of the above limitations, the report contains only suggestions as to the magnitude of fish losses and the costs of screening."

<u>Not all diversion facilities entrain fish or eggs</u>.

The assumption that small diversions will divert fish, eggs and larvae from the channel in proportion to the amount of water diverted does not appear to be supported by previous study results. The 1972 sampling by David H. Allen of seven siphons on Sherman Island appears to confirm that some siphons don't divert any Striped Bass fish or eggs while others do. See attached Table 1 from such study. Possible important variables could be depth of intake, configuration of intake, channel flow characteristics and desirability of habitat near the intake.

<u>Geological distribution of endangered fish in the Delta is certainly not uniform and probably not complete</u>.

Test results and logic support the proposition that there is a greater possibility of diversion of endangered fish by way of diversions from locations containing the greatest numbers of such fish. It doesn't make sense to install fish screens to protect Winter-Run Chinook in areas where Winter-Run Chinook numbers are small or non-existent.

Screen Technology.

Technology and hardware appear to be available to screen small fish (1 inch or greater in length) but not eggs and larvae. Clogging and effectiveness in saving fish need further evaluation.

Cost

Our screen test leads us to believe that installation cost will exceed $50,000 per siphon site. A major component is bringing electrical power to the site. Operation and maintenance costs are unknown. If we assume 1600 siphons, the installation cost estimate would be about $80,000,000.00.

Rational Approach to Screening.

A rational approach to the screening of Delta diversions would be as follows:

1) Evaluate the cost and benefit of screening intakes vs. other measures to protect and enhance the desired fish species. Consideration should be given to other methods of reducing the diversion of fish such as baffles, reconfiguration of intakes and sonic devices along with increased flushing flows, increased outflow, hatcheries, etc. Such an evaluation should include identification of proven screening devices and related screen efficiencies.

2) Assuming screening diversions is the desired approach, determine which intakes should be screened and establish a priority list. For example, screening some intakes along the Sacramento River might be more beneficial than screening others in Turner Cut.

3) Identify the devices to be installed including a method whereby the device can be easily bypassed if plugging occurs so that crop loss can be avoided.

4) Provide the funding for installation, operation, maintenance and replacement without cost to Delta farmers.

Responsibility for Cost of Screening or Other Mitigation.

We do not believe that Delta farmers should be asked to pay for installation, operation, maintenance or replacement of fish screens. The delta lands were fully developed and irrigated long before there was a fishery problem. With the subsidence of the peat soils, we believe that each year more of the water used by Delta crops comes from seepage and thus the amount directly diverted has probably substantially decreased since the late 1960's. The evidence indicates that high populations of competing species of Salmon and Striped Bass co-existed until about the time that the State Water Project (SWP) commenced operations. Both the CVP and SWP at times reduce Delta outflow and/or draw water away from the natural river courses thereby forcing fish, eggs and larvae from their natural areas and routes. In the case of both the Delta Smelt and Winter-Run Salmon, such actions appear to increase the possible exposure to diversion int he Delta. We recognize the probability that other actions coinciding with the operation of the SWP have adversely affected the fisheries, however, we know of no such action attributable to Delta farmers. The cost of screening Delta diversions is very substantial and well beyond the payment ability of Delta farmers. Imposition of such a burden would unjustly destroy Delta agriculture and the resulting benefits to waterfowl and other wildlife. With the destruction of agriculture, the ability to maintain levees will also be lost.

By law and agreement, only water surplus to the needs of the Delta and other watershed of origin areas was to be exported by the SWP and CVP and the Delta was to be maintained as a common fresh water pool. Additionally, the SWP and CVP were to provide salinity control for the Delta and a master drain was to be constructed for the San Joaquin Valley. See generally California Water Code Sections 1215 through 1222, 10505, 11460, 12201 through 12205 and Public Law 86-488, 74 Stat. 156.

The involvement of both the Federal and State governments as the instruments for export of water from the Delta has eliminated the possibility of unbiased regulatory action by our State and Federal agencies. This bias unfortunately permeates every aspect of water in California.

The burden for correcting the adverse impacts caused by the SWP and CVP should not be imposed upon others. The projects should mitigate all of their damages; they should be required to meet the affirmative obligations related to salinity control; and their exports should be limited to water which is truly surplus. Only after such steps are taken can the rightful burden of others be properly and fairly ascertained.

We recognize that many steps are being taken to attempt to correct the wrongful actions of the SWP and CVP, some of which would appear to alter the possible impact of unscreened diversions.

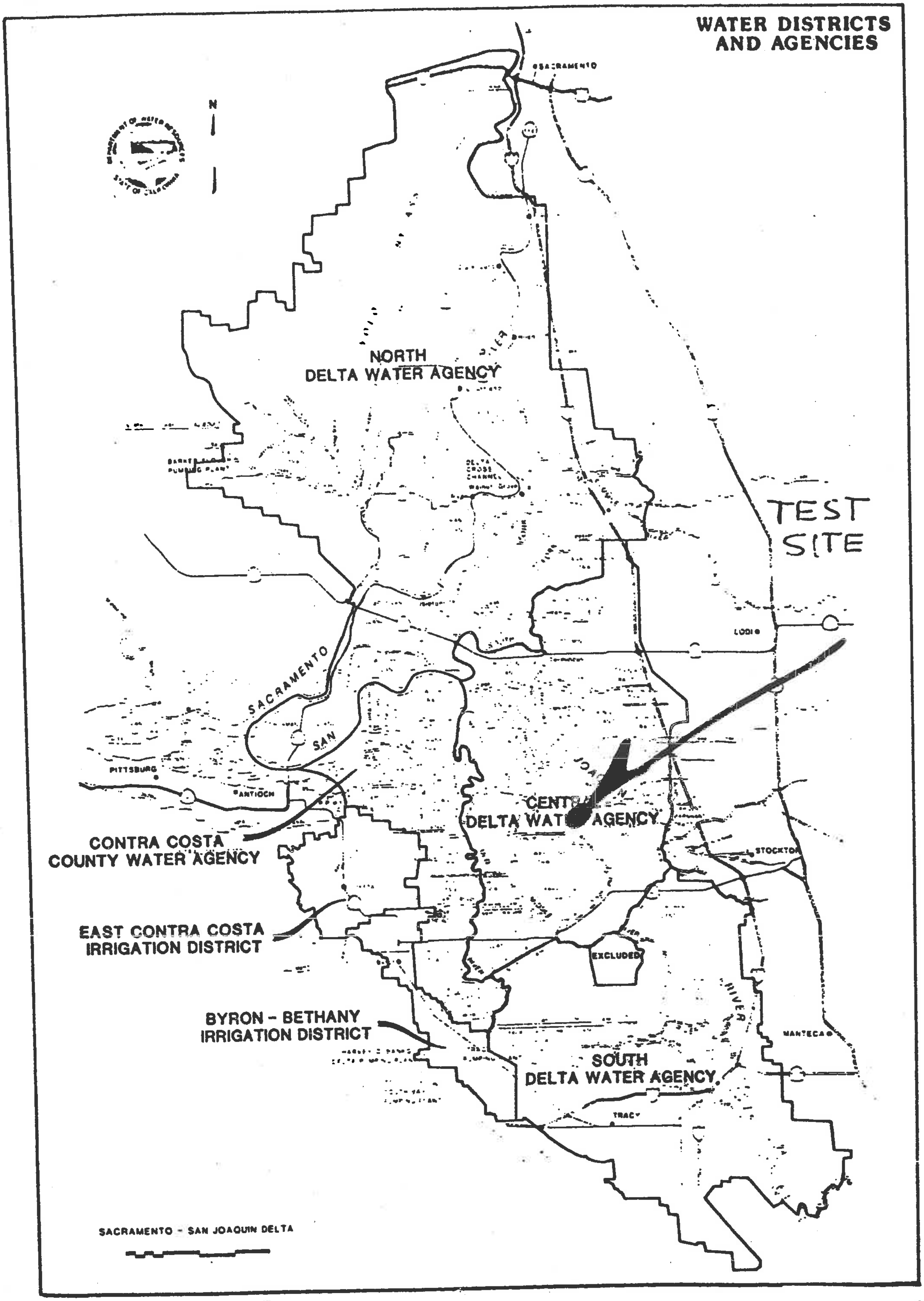
Although we have preliminarily concluded that there is little justification for screening the multitude of small diversions in the Delta or even along the Sacramento River,

we are willing to positively participate in developing a rational and fair approach to screening agricultural diversions in the Delta and along the Sacramento River.

Yours very truly,

DANTE JOHN NOMELLINI
Manager and Co-Counsel

DJN:ju
Enclosures



WRINT CDWA EXHIBIT 5

1992 AGRICULTURAL DIVERSION FISH IMPACT STUDY
MCDONALD TRACT

Species	Larval Fish (MAY - AUGUST) *FISH SCREEN Off	On	Total	Juveniles and Older (JUNE - AUGUST) *FISH SCREEN Off	On	Total
Chameleon goby	1276	589	1865	0	0	0
Threadfin shad	1766	60	1826	0	0	0
Striped bass	0	0	0	0	0	0
Centrarchids	9	0	9	2[1]	1[2]	3
Delta smelt	0	0	0	0	0	0
Sacramento splittail	0	0	0	0	0	0
Mosquitofish	3	0	3	4	23	27
TOTALS:	3054	649	3693	6	24	30
Eggs:						
Striped bass	0	0	0	0	0	0
Threadfin shad	4	14	18	0	0	0
TOTAL EGGS:	4	14	18	0	0	0

NUMBER OF FISH CAUGHT

[1] Green sunfish

[2] Bluegill

* Sampling Times were equal for Screen off and on.

David H. Allen
1972 Sampling

TABLE 1

Total Catches of Striped Bass Eggs and Young From Agricultural Diversions on Sherman Island

Total Catch Striped Bass Young
Siphon

Date	S-2	S-3	S-4	S-6	S-7	S-9	S-10	Total
5-3							3	3
5-5							3	3
5-9						3	0	3
5-11						9	4	13
5-15						0		0
5-17						1		1
5-19		8				0		8
5-23		11	1			0		12
5-25		59	3					62
5-31		64	20		39			123
6-2		43	2		19			64
6-14							22	22
7-7		2		2				4
7-11		4						4
7-14	2							2
Total	2	191	26	2	58	13	32	324

Total Catch Striped Bass Eggs
Siphon

Date	S-2	S-3	S-4	S-6	S-7	S-9	S-10	Total
5-3							0	0
5-5							0	0
5-9						0	0	0
5-11						49	0	49
5-15						131		131
5-17						7		7
5-19		35				5		40
5-23		2	1			0		3
5-25		74	15					89
5-31		4	3		1			8
6-2		0	1		1			2
6-14							0	0
7-7		0		0				0
7-11		0						0
7-14	0							0
Total	0	115	20	0	2	192	0	329